DEVELOPMENT OF A PARAMETRIC COST ESTIMATING MODEL FOR UNIVERSITY OF ALASKA SYSTEM RENOVATION CONSTRUCTION PROJECTS

By

Gregory Puckett, B.S.

A Project Submitted in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF SCIENCE

in

Engineering Management

University of Alaska Anchorage

December 2016

APPROVED:

Steve Wang, Ph.D., Committee Chair
Seong Dae Kim, Ph.D., Committee Member
Gary Kretchik, M.S., Committee Member

LuAnn Piccard, M.S., Chair
Department of Engineering Science and Project Management
Robert Lang, Ph.D., Associate Dean
College of Engineering

ABSTRACT

Early building construction planning strategies provide the foundation for the subsequent performance and success of a project. Cost estimates for projects with minimal scope of work definition, but within the range of accuracy established by industry-recognized professional standards, represent a critical factor in screening potential endeavors against competing alternatives and establishing baseline budgets. Parametric cost estimating models provide owners and managers a tool to develop a prediction of costs and determine the feasibility of a project.

This study investigated the process and performance of parametric cost estimates for building renovation projects by analyzing cost data and construction documentation for 50 University of Alaska system jobs from seven campus locations. Cost data was normalized for inflation and location. Project construction documentation was analyzed to determine the extent of the performed scope of work in terms of both building area and systems. The data was entered into a statistical software package and assessed for correlation between project cost and building area/systems criteria. A cost estimating relationship algorithm was formulated from the analysis to establish a parametric model. The generated model was determined to provide a quality fit to the data and adequate predictor of renovation project costs.

The work demonstrates that a representative parametric cost estimating model can be formulated for University of Alaska system renovation projects. Given the current State of Alaska fiscal climate and the financial challenges facing the statewide higher education system, developing a tool to facilitate the planning, budgeting, and feasibility assessment of competing project alternative represents an important accomplishment that can provide guidance to university managers, system regents, and state legislators.

Table of Contents

Page

List of Figures

Page

List of Tables

Appendices

Page

Acknowledgement

First and foremost, I would like to thank my family in Texas and Arizona for their encouragement and support during the challenging journey to complete my degree. They are always a source of inspiration.

I would like to thank the University of Alaska Anchorage College of Engineering and particularly, the Engineering, Science, and Project Management Department for the opportunity to pursue my degree. The flexibility and support provided as I endeavored to finish my course of study remotely from Fairbanks and Houston, Texas proved invaluable in completing my program.

Additionally, I would like to thank my advisor Professor Hsueh-Ming Wang, Ph.D. for his guidance and support during my degree program. I am grateful to all the instructors who taught the courses I attended including Norman Sams, Greg Kinney, Gary Kretchik, Bruce Davison, J.D., and Engineering Management Program Chair Seong Dae Kim, Ph.D. The assistance provided by Meuy Saechao and Andrew Tibor from the ESPM Department is truly appreciated.

Finally, I would like to thank the University of Alaska Anchorage Facilities Planning and Construction and University of Alaska Fairbanks Facilities Services Design and Construction for the provision of cost data necessary to build a cost estimating model to complete this project. The Department's respective assistance is appreciated.

Chapter 1 Introduction

Cost estimating provides stakeholders in construction projects of various forms a powerful tool to gauge the financial resources necessary to complete the planned endeavor. Early assessment of project feasibility guides stakeholder decision making and lays out a roadmap for how and if a project is initiated and developed. The cost estimate is the product of "the predictive process used to quantify, cost, and price the resources required by the scope of an investment option, activity, or project" (Amos (Ed.) & Dysert, 2010). Without the financial baseline provided by a cost estimate, projects would not have a cornerstone metric upon which to determine the performance of the investment endeavor.

The estimating process combines a variety of processes and information into a coherent format with a cost estimate of variable accuracy as the outcome. The inputs are depicted below:

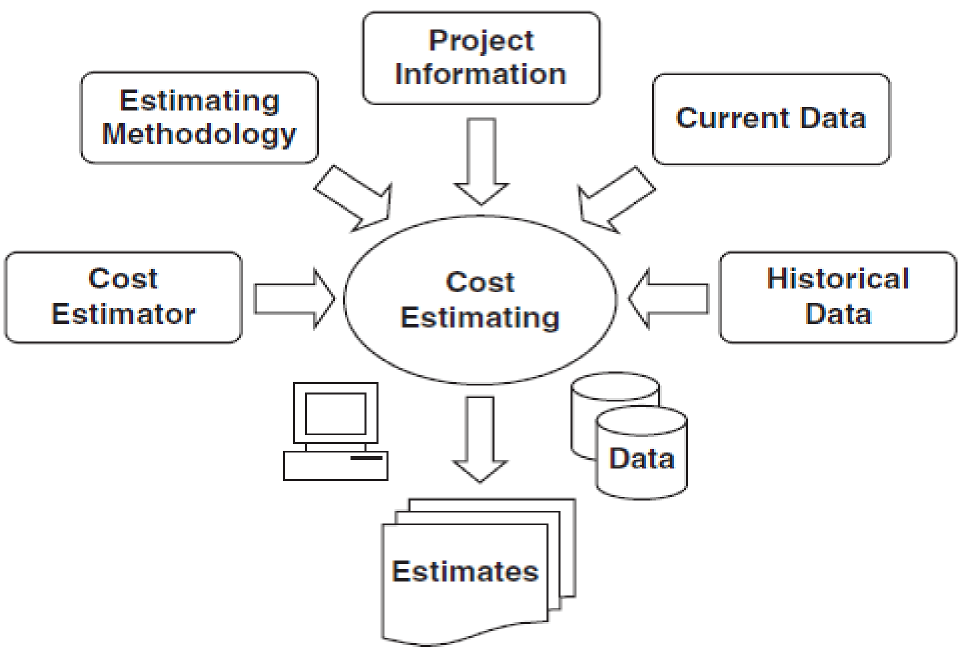

Figure 1. Cost Estimating Inputs (Kim, Shin, Kim, & Shin, 2013)

This Capstone Project utilizes the inputs depicted above to generate a cost estimating model for University of Alaska system renovation construction projects. Project information and data – both historical and current fiscal year - are obtained from the University of Alaska Anchorage Facilities Planning and Construction and the University of Alaska Fairbanks Facilities Services Design and Construction departments, as well as the online plans room www.aeplans.com.

The methodology employed will be parametric cost estimating. Parametric cost estimating may be defined as "a mathematical representation of cost relationships that provides a logical and predictable correlation between the physical or functional characteristics of a project (plant, process system, etc.) and its resultant cost" (Dysert, 2005). To develop a representative model for building renovation construction projects, the following basic criteria are necessary:

- Project Cost Data
- Project Physical Data/Information (square footages/scope of work assessments)
- Project Dates/Locations

A statistical software package is required to efficiently perform the modeling to formulate a parametric cost estimating relationship. The software package Statgraphics is used to analyze the data and provides interpretations of the results. Additionally, cost estimating judgement is provided by the author of this study with respect to the assessment of the scope of work for each project based on the project drawings - floor plans/description; namely, the extent of renovation/mechanical-electrical-plumbing (MEP) work/quality of finishes incorporated into the renovation project.

Undergirding the development of the parametric model, a literature survey of cost estimating in general, and a more detailed study of parametric estimating and its application to building projects is provided for background and context. The process and strategy for building the parametric model through establishment of a research methodology directs the project to an analysis of the available data. Statistical trends in the data are determined by employing multiple regression techniques and analysis with general linear models. Results from the statistical analysis are validated with data from university system building renovation projects to predict costs and subsequently compared to actual normalized costs.

The study is summarized with conclusions about the product of the model. Recommendations for further inquiry are proposed based on the study. Ideas and strategies to improve the existing system for engaging in university building renovation projects are provided, based on experience from the author’s background and current employment responsibilities and duties.

Chapter 2 Literature Review

2.1 Conceptual Cost Estimating

Developing a cost estimate for any type or classification of project represents one of the most important activities related to the endeavor. The outcome of the process of cost estimating provides guidance – within defined accuracy ranges - on the amount of funding required to perform the project as applied to the quantity of materials, labor, land and other resources. Four fundamental steps are involved in the process:

- Discern the extent of the endeavor to be accomplished
- Assign financial expenses to the activities and items
- Adjust the expenses to capture indirect costs and profit
- Interpret the results as a guideline for drawing conclusions

These elements are present in cost estimating regardless of the field of endeavor (Amos (Ed.) & Dysert, 2010).

Cost estimates may be categorized based on different, but somewhat related factors. The accuracy of an estimate – the difference between the projected costs versus the actual costs – represents the most important characteristic to project owners and financially obligated stakeholders. According to AbouRizk, Babey, and Karumanasseri (2002), the accuracy of the estimate should be standardized or normalized as a deviation of the estimated cost to the actual cost of the project or endeavor. This mathematical relationship can be represented per the following Equation 1:

Deviation = [{(final project cost) – estimate at phase}]/estimate at phase

In addition to accuracy, the following factors may be used to categorize cost estimates:

- Scope definition
- Purpose of estimate
- Estimate procedure
- Expenditure of resources to perform estimate

The following depicts a matrix representation of estimate categories, factors, and classifications:

Table 1. Generic Cost Estimate Classification Matrix (AACE International, 1997)

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical +/- range relative to best index of 1 [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgment	4 to 20	1
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed, but Primarily Stochastic	2 to 6	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Primarily Deterministic	1 to 3	5 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	1	10 to 100

Notes: [a] If the range index value of "1" represents +10/-5%, then an index value of 10 represents +100/-50%.
[b] If the cost index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%.

Based on the matrix above, cost estimating techniques fall into two categories: Deterministic and Stochastic. Estimates that use stochastic estimating techniques are commonly referred to as conceptual estimates. The matrix indicates the differences between the technique categories with respect to project definition, end use, expected accuracy, and preparation effort. Deterministic estimates require more scope definition and expended effort, but afford greater accuracy. Conversely, conceptual estimates are geared toward projects that have less definition and require considerably less effort to perform, however with less anticipated accuracy. Parametric cost estimates fall into the conceptual estimate category.

Amos (Ed.) and Dysert (2010) discuss the choice of conceptual estimating for various situations and needs. Generally, conceptual estimates are appropriate and desirable for the following purposes:

- Create a preliminary filtering estimate for a potential endeavor
- Assess the practicability of an endeavor
- Evaluate project options
- Assess financial consequences of project options
- Set an early budget to baseline subsequent project financial performance

Definitive accuracy is not the purpose or intended characteristic of a conceptual estimate. These estimates provide a decision-making tool for stakeholders to determine project feasibility and options at the nascent stage of scope development and definition.

According to Akintoye (2000), numerous factors related to a project or endeavor affect the process of cost estimating. The elaborateness and intricacy or a project, size and location of the endeavor, prevailing market forces, means and design, restrictions related to the property, and owner's monetary position all influence the development and final disposition of the cost estimate.

Because of the limited available resources and ill-defined project scope, conceptual estimating is regarded as a difficult endeavor. Three basic shortcomings inure to this category of cost estimate:

- Lack of clarity and difficult to understand
- Cumbersome to use on actual projects
- Stakeholders are hesitant or unwilling to be confident in the results

These elements present a challenge to the cost estimator formulating conceptual estimates (Adel, Elyamany, Belal & Kotb, 2016).

The use of historical data is frequently used to develop a conceptual cost estimate. With limited scope definition attendant with the conceptual cost estimate formulation, data from past projects of a similar end use and with comparable physical dimensions and characteristics provide an important element to increase potential accuracy. However, consistent and complete data is not always accessible to the cost estimator. Under these circumstances, constructive use of available data is required to obtain the best results for the estimate (Kim, Seo & Hyun, 2012).

With limited scope of work definition generally available at the stage of applicability for conceptual estimating, evaluation of potential scope alteration should be considered when initially developing the cost estimate. According to Kim et al. (2012), three elements are involved in the likelihood of significant project scope change:

- Major ownership stakeholder assurance of scope
- Endeavor intricacy and novelty
- Level of technology involved in constructing project/end output

Variability of market and physical conditions attendant with the project, sophistication and complexity of the project, and use of advanced technology all potentially contribute to a higher probability of significant project scope alteration.

Serpell (2005) posits that the conceptual cost estimating is an ambiguous and imprecise process due to ill-defined scope and lack of pertinent information regarding potential costs. A major emphasis for successfully executing meaningful conceptual estimates lies with the estimator – their experience with and knowledge about the process and the proposed scope of work and associated costs. Resources required to enhance the likelihood of formulating a quality conceptual estimate include a seasoned and skilled estimator, data, and an information processing system to aid in the analysis or the available project data. Items that influence the quality of conceptual estimates are indicated in the table below:

Table 2. Factors Affecting Conceptual Estimate Quality (Serpell, 2005)

Scope	Information	Uncertainty	Estimator	Procedure
Quantities Definition Design approach State of design Completeness Detail Information quality Consistency Continuity Project nature Project technology	Processing Sought Availability Validity Completeness Relevance	Technology Project Environmental Productivity Market Construction Project nature	Talent, skills Experience Effort applied Expertise Judgment Knowledge Common sense Team ability	Mistakes Time available Measurements

With estimate accuracy a preeminent concern, the figure below indicates major factors contributing to the formulation of estimates closer to the actual project costs:

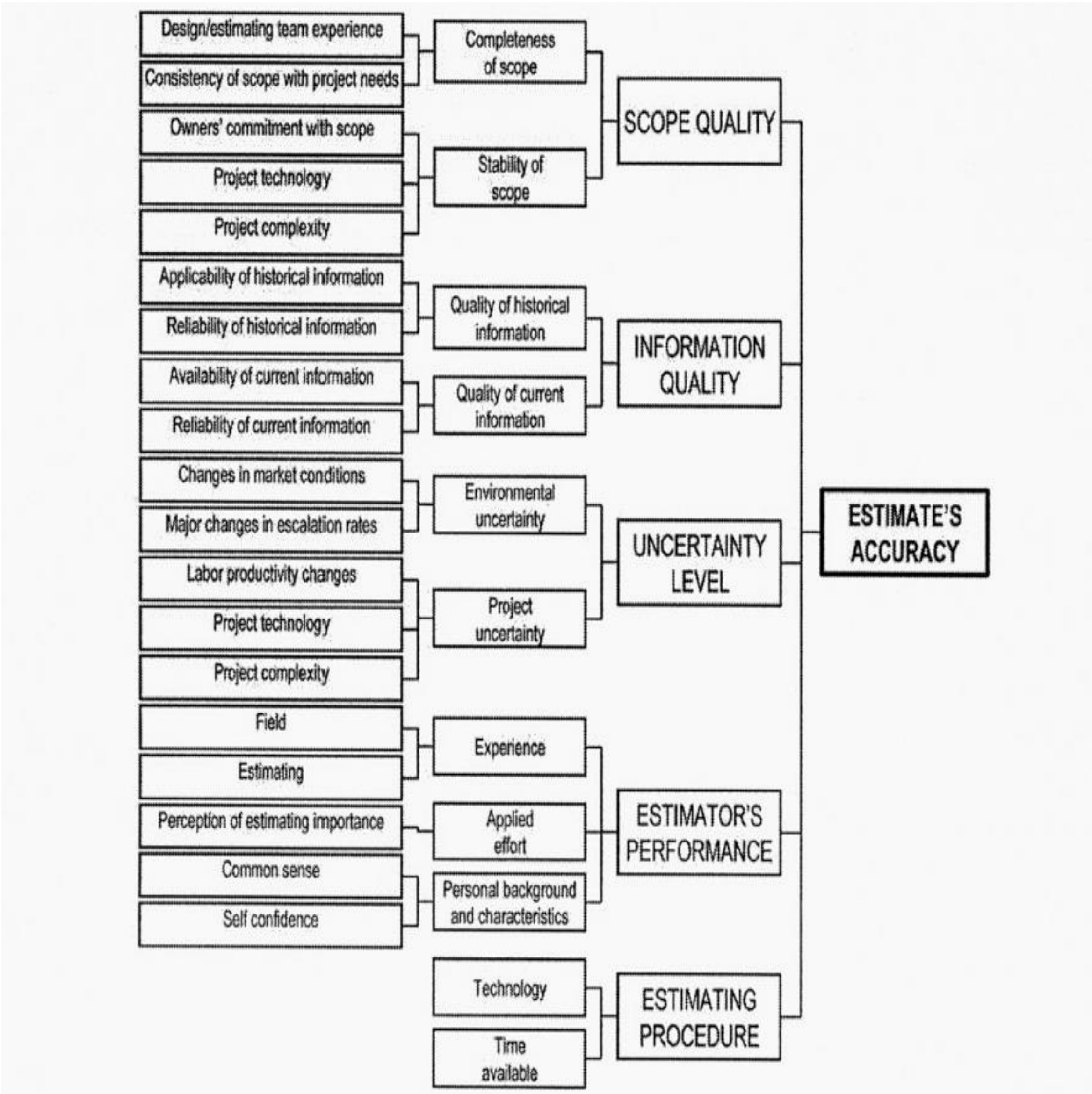

Figure 2. Factors That Influence Conceptual Estimate Accuracy (Serpell, 2005)

Project definition that remains relatively static through the planning and execution phases, solid historical and current information, and the estimator's skill and training represent critical elements leading to a more accurate conceptual estimate.

2.2 Parametric Model Development and Implementation

Parametric cost estimates, a class of conceptual cost estimates, are normally performed in the nascent phase of an endeavor. Project documentation such as plans and guidelines are rarely available at this early stage. However, project stakeholders require some range of potential costs to execute the project or determine if it is feasible to perform at all. Other project options may be available and need to be investigated. Formulating a budget, even at the earliest stages, is important in securing financing and authorization from owner's to proceed with the project. In light of the uncertainty, a means to gauge required resources to execute is still necessary. Conceptual estimates, and specifically parametric estimates provide the method to accomplish this end (Oberlender and Trost, 2001).

According to Association for the Advancement of Cost Engineering International (1990), a parametric estimate

> describes estimating algorithms or cost estimating relationships that are highly probabilistic in nature (i.e., the parameters or quantification inputs to the algorithm tend to be abstractions of the scope). Typical parametric algorithms include, but are not limited to, factoring techniques, gross unit costs, and cost models (i.e., algorithms intended to replicate the cost performance of a process of system).

The basis for this study is conceptual parametric estimating. The items required for the successful development of a parametric estimating model have been enumerated and described in cost estimating literature.

The genesis of parametric estimating involves the development of a practice and strategy to forecast design, fabrication, and assembly costs for military aircraft to be deployed in World War II. The concept of "learning curves" – the idea that processes and procedures become more efficient over a product's manufacturing lifetime – provided the basis for developing parametric estimates (U.S. Department of Defense, 2000). An extension of the nascent process was instituted by the Rand Corporation after World War II and also developed the concept of a Cost Estimating Relationship (CER). The parametric estimating process was extended to include defense project weapons systems and utilization of parameters like velocity, range of operations, and altitude limits for proposed aircraft (DOD, 1999). The upshot of the military use and development of a parametric cost estimating system involved the publishing of a standardized process outlined in the Parametric Cost Estimating Handbook.

Melin (1994) summarizes some of the requirements for developing a parametric estimate. Cost data from finished projects that are comparable in nature and function and physical attributes and dimensions (parameters) provide essential information to initiate the estimate. He indicates, as buttressed by consistent claims in the available literature, that estimator knowledge and seasoning is essential in the preparation of a parametric cost estimate. An information processing and warehousing system is another important requirement to facilitate efficient analysis and storage of pertinent information.

Bajaj, Gransberg, and Grenz (2002) indicate that the systematic use of effectual cost accounting principles and practices, as well as aforementioned organized cost data are necessary for a parametric estimate. Additionally, proper data preparation, implementation of statistical principles, and use of a defined process guide are requirements to ensure a quality estimate.

According to Ahn, Kim, Yong-Chil, and Chang-Taek (2012), frequent use of parametric estimates at the nascent design phase is a sound strategy in the planning stage of projects. The use of the technique is appropriate due to a lack of scope definition on most projects at this stage. The cost and required resource expenditure to prepare parametric estimates make them an attractive alternative, especially if sufficient data from previous projects is available for inclusion in the model development.

Cost estimating relationships can be judged by the effectiveness of model in explaining the variation in predicted and actual project or endeavor costs. Parametric estimates incorporate statistical techniques into their formulation of a model to describe how costs vary with defined parameters. The quality of the CER can be assessed by value of statistical metrics derived from an analysis of the cost and parameter data. Regression techniques are frequently employed to model the data. The Correlation or Pearson coefficient R^2 indicates the percent of the deviation in established independent parameters dictated by the regression model. The higher the value R^2, the more accurate the model (Lamboglia, Gaudenzi, and Joumier, 2008).

According to Whiteside II (2004), employing regression techniques in parametric models provides quickness and flexibility to the estimator. Resources consumed searching for data can be better used on other functions. Regression models enhance the ability of project participants to assess risk at the early stage of projects.

Kwak and Watson (2005) indicate that detailed data regarding costs for supplies and equipment, as well as human resources, are not required to formulate a parametric estimate. Since the estimate basis is derived from historical costs and performance metrics or physical attributes, the need for specific costs for work or design elements and supplies is not as important as in quantity-based or definitive estimates. The author's depict parametric estimates with respect to project phases in a project management process environment. This depiction is provided below:

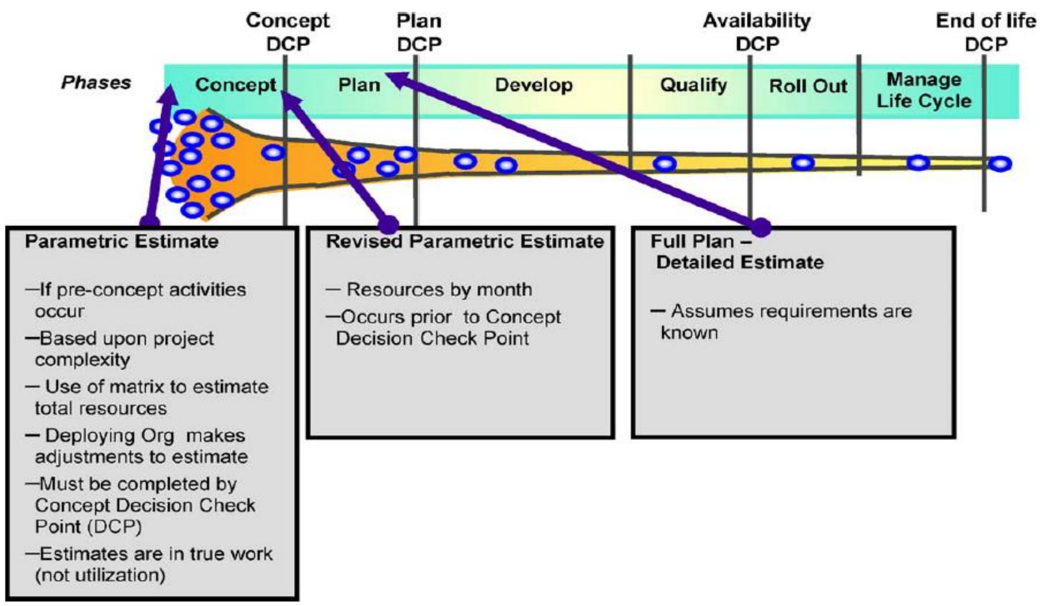

Figure 3. Parametric Estimates in a Decision Check Point/Phase Gate Process (Kwak and Watson, 2005)

The project management process shows the context of parametric estimates at the earliest stage of project development.

The same study by Kwak and Watson (2005) discusses the value of the parametric estimating process, albeit in a technology-driven setting such as software or advanced product development. The findings from the research indicates that even though parametric estimating is challenging and generally lacks highly accurate estimates, the technique provides considerable value in the nascent stage of project development. The scalability of the estimates represents a major advantage over other early project stage estimating techniques. Scholarly literature is extant with respect to parametric estimating for construction projects of various types. A survey of this literature, and how it provides the impetus for this study, is provided in the following section.

2.3 Estimating Construction Projects with Parametric Models

Parametric cost estimating models may be formulated for a variety of construction projects. As previously indicated in this study, these models are appropriate in the nascent stages of project development when scope of work and building systems are ill-defined. The use of parametric models in the construction sector is an industry accepted practice early in the planning process. The reduced expenditure of resources and compressed timeline makes parametric estimating for construction projects attractive at this stage (Watson and Kwak, 2004).

Bajaj, et al (2002) also recognize the usefulness of parametric modeling applied to the construction sector. The efficacy of parametric estimating in construction mainly relates to the compressed timeline provided by the technique. Prime contractors can effectively solicit and process pricing from specialty contractors and easily include this pricing in their models. Data from past projects with similar scope of work and end usage can be efficiently adjusted for location and indexed for inflation.

Latief, Wibowo, and Iswara (2013) enumerated characteristics that undergird an effective parametric construction estimating model. These factors include:

- Acceptable level of accuracy
- Alacrity and simplicity of use
- Simplicity of revision
- Model transparency
- Constancy in variables for long-term use of model

The value of the abovementioned characteristics are repeatedly referenced in the available literature.

Larson (2002) indicates a fundamental methodology for construction project parametric estimates involves recognition of the intended use of the structure and declaring a dedicated floor area requirement. These elements form the cornerstone of the parametric model and provide a baseline early estimate for the project. The estimate in subsequently refined with decisions concerning building systems and assemblies to achieve a higher degree of accuracy as scope definition becomes more defined.

According to Meyer and Burns (1999), a dedicated parametric estimating system is used by the U.S. Department of the Air Force for certain aspects of construction projects. The system – named the PACES 99 system – is configured to minimize the input required to generate a design cost estimate by supplying predetermined values for engineering and design deliverables associated with a given project. Utilizing these models reduces mistakes and oversights that frequently occur during the nascent design phase. The model lends efficiency and reliability to early project design estimating.

Similar to the Department of the Air Force practice, the U.S Army Corps of Engineers utilizes a software-based application to develop estimates from established parametric models. The application – named Control Estimate Generator (CEG) – is capable of producing comprehensive data to feed into a parametric model. This procedure provides a baseline control estimate to gauge financial performance during project execution (Melin, 1994).

Jrade and Alkass (2007) provide a methodology that integrates multiple software applications into an overarching system that produces parametric estimates and life-cycle cost analysis of proposed projects in tandem. The system employs various modules to generate cost profiles under different operational scenarios. The units include a parametric model, a drafting module, dedicated Visual Basic for Applications operability, and a statistical module for data analysis and decision making.

The Washington, D.C branch of the General Services Administration (GSA) employs a parametric estimating model to generate cost estimates for various federal agency development projects. Frequently, limited information is available regarding a proposed project and, as a result, a costly estimate with definitive building elements is unwarranted. For GSA, the development and implementation of a parametric model is appropriate given the regular need to formulate cost estimates for projects with ill-defined scope at the incipient stage of planning. It is noted that the model be updated regularly with current cost data to capture changing construction market conditions (Davis, 1998).

Multiple regression analysis is a preferred statistical technique employed in the development of parametric cost estimating models. Lowe, Emsley, and Harding (2006) indicate multiple data type independent variables representing various items and factors employed in constructing a building may be used to provide a wide-ranging data set for the regression model. The study involved development for a parametric model for large new construction residential projects. Variables included nominal types (yes/no), ordinal types (ranked or Likert scale) and interval types (floor-surface areas/stories above grade/etc.) Nearly all physical elements or components of construction were included in the variable catalog. Additionally, construction project processes like contract arrangements and delivery format as well as project site elements such as location and topography were assigned values and incorporated into the parametric model. The variables for the model are shown below:

Project strategic variables			
Contract form (O)	Procurement strategy (O)	Tendering strategy (O)	
Duration (S/weeks)	Purpose (O)		
Site related variables			
Site access (O)	Type of location (O)		
Topography (O)	Type of site (N)		
Design related variables			
Air conditioning (S/£)	Function (S/£)	Stories below ground (S/number)	Shape complexity (O)
Ceiling finishes (S/£)	GIFA (S/m^2)	Mechanical installations (S/£)	Special installations (S/£)
Electrical installations (S/£)	Height (S/m)	Piling (N)	Stairs (O)
Envelope (S/m^2)	Internal doors (S/£)	Protective installations (S/£)	Substructure (O)
External doors (S/£)	Internal walls (S/£)	Quality (O)	Structural units (S/number)
External walls (S/£)	Internal wall finishes (S/£)	Roof construction (O)	Upper floors (O)
Floor finishes (S/£)	Number lifts (S/number)	Roof finishes (S/£)	Wall-to-floor ratio (S/ratio)
Frame (O)	Stories above ground (S/number)	Roof profile (O)	Windows (S/£)

Note: N=nominal (e.g., piling: 0=no piling, 1=piling); O=ordinal (e.g., shape complexity: 0=low, 1=medium, 2=high); and S=scale (e.g., external doors: a proportional scale based on relative costs).

Table 3. Variables for Residential Development Parametric Cost Estimating Model (Lowe, Emsley, and Harding 2006)

The study demonstrates how a robust and detailed approach to assigning variables and combining independent data type can be used to develop a parametric cost estimating model for large scale projects.

According to Chan and Park (2005), issues attendant with regression analysis performed in the parametric cost estimation process for construction projects may impact the veracity of the results. They express concern regarding the presence of multicollinearity – the occurrence of moderate or high correlation and interdependence among predictor variables in a multiple regression model – with respect to predicted project costs. It is suggested that implementing a stepwise regression process would minimize the prospect of introducing multicollinearity into the results.

Other studies have addressed the problem introduced by the presence of multicollinearity in the results of a multiple regression analysis. Sonmez (2008) indicates in his study that employs multiple regression and bootstrapping – a probabilistic technique for range estimating of costs –

that meaningful multicollinearity should be recognized and quantified in a model. Quantifying multicollinearity may be achieved by determining values for a model's variance inflation factor (VIF). High VIF values (10 or larger) demonstrates high correlation between certain predictor variables.

Ji, Park, and Lee (2010) suggest that a strategy involving the application of data preprocessing techniques to the input parameters for a multiple regression, especially if numerous predictor variables and large data sets will be entered into the model. They posit that employing data preprocessing for large models reduces that potential of unusual residual values and leads to a more efficient model building process. Predictor variable values that may influence the production of incorrect results can be excluded before the stepwise regression process is executed.

Kim et al. (2012) propose the use of multiple type of estimates to obtain a final feasibility or screening estimate in the early project planning stage. The implementation of a hybrid estimating model combines typical historical data parametric estimates with more definitive material or building assembly capacity or count estimates in a comparative process. They declare several advantages accrue to this estimating strategy including:

- The hybrid process is well-suited to mixed-use building projects
- Combining the methodologies mitigates ambiguity accompanying unclear scope
- The hybrid method provides flexibility to the estimator
- Enhanced clarity is provided concerning costs
- Compensation for missing historical data potentially impacting a regression model

Utilization of hybrid models boosts the confidence of project stakeholders in the estimated costs of a project at the early stages of planning and development.

Oberlander and Trost (2001) suggest that more study and analysis of the use of parametric models for building and infrastructure construction estimating is required to determine and gauge the project elements that influence the accuracy of cost estimates. Early stage estimates that provide higher accuracy will accrue substantial benefits to all affected project stakeholders and buttress improved project performance.

The review of the literature provides motivation to advance the study of parametric estimating of building construction projects. The advantages provided to project participants from higher accuracy early stage estimates are clear and definitive. High quality early stage estimates can enhance project execution and cost performance, regardless of the type of project undertaken.

Chapter 3 Research Methodology

3.1 Problem Definition

Organizations or institutions, whether existing in the private or public sectors, require the capacity to evolve and grow as time passes. A private business must have a place to house its operations and perform its day-to-day functions. Public sector institutions, from branches of government, to public utilities, or state-funded universities and schools, require facilities to perform their requisite functions and duties. The facilities used by institutions must be maintained, upgraded, and occasionally replaced over a period of time. This process requires capital expenditure and the formation of budgets to apportion costs over time.

With limited resources available to the institution, budgets have to be established to pay for the costs involved in upgrading and replacing building facilities to meet the needs of the stakeholders. Cost estimates represent a crucial element in budgeting expenditures for the upgrade, replacement, or new construction of facilities regardless of institutional category. For larger institutions that continually face the prospect of multiple ongoing and upcoming construction projects, a cost estimating system that predicts project costs and facilitates the budgeting process can prove invaluable to proper apportionment of available funds that are appropriated for maintenance, upgrade, expansion, and replacement of facilities.

The University of Alaska system represents an institution that engages in multiple vertical construction renovation projects in a given year. The process, purview, and repetitiveness of the projects makes the university system an excellent source of data and candidate for the development of a parametric cost estimating model based on elements required for such a model. The vast majority of the renovation projects are associated with office space, classrooms, assembly spaces, laboratories, and common/building core areas such as corridors, restrooms, and utility rooms. Given that the University of Alaska is a public institution, project data is available on request for investigation, preparation, analysis, and input into a parametric cost estimating model. Given the current fiscal situation facing the State of Alaska, a cost estimating model that screens potential projects for execution at the earliest stage of planning, with a minimum amount of resources expended, could become an integral element in the planning for system-wide construction renovation projects. This fact provides the basis, justification, and motivation to pursue this study and Capstone Project.

Background/Source Information

The University of Alaska system encompasses several campuses that are centered on three main branch locations – Anchorage, Fairbanks, and Juneau. Actual campus locations include the following branches and locales:

- University of Alaska Anchorage (UAA)
    - Main Campus (Anchorage)
    - Kenai Peninsula Campus (Kenai)
    - Kodiak Campus (Kodiak)
    - Mat-Su Campus (Palmer)
- University of Alaska Fairbanks (UAF)
    - Main Campus (Fairbanks)
    - Bristol Bay Campus (Dillingham)

- Chukchi Campus (Kotzebue)
- Interior-Aleutians Campus (Fairbanks)
- Kuskokwim Campus (Bethel)
- Northwest Campus (Nome)
- Correspondence/Rural Campus (Fairbanks)

- University of Alaska Southeast (UAS)
  - Juneau Campus (Juneau-Auke Bay)
  - Ketchikan Campus (Ketchikan)
  - Sitka Campus (Sitka)
- Prince William Sound Community College (PWSCC)
  - Valdez Campus (Valdez)

Construction projects for the University of Alaska System are managed by the respective departments of the branch overseeing the campus where the project occurs and in concert with University of Alaska Statewide Procurement. Project cost data and construction documents that will be used to develop the parametric cost estimating model will be requested from the following departments and offices:

- UAA Facilities Planning & Construction
- UAF Facilities Services – Design & Construction
- UAS Facilities Planning & Construction
- U of A Statewide Procurement

Construction floor plans for each project deemed congruent with the model scope and guidelines will be analyzed for the independent variable data integrated into the cost model.

Identifying significant cost drivers for the renovation construction projects to employ as predictor variables for development of a model is critical to building a model that has a high probability of generating predicted costs based on the accuracy criteria established for parametric cost estimates. According to Parker (2014), building floor area is a dominant driver of construction costs, in addition to Mechanical-Electrical-Plumbing (MEP) systems, quality of finishes, site work, and specialty equipment. Chan and Park (2005) concur with assessment of gross floor area as a main cost driver. Lowe, Emsley, and Harding (2006) found that gross interior floor area and building systems were significant cost drivers associated with scope of work within the building envelope. Ahn et al. (2012) determined that Gross Floor Area represented the principle statistical attribute with highest correlation coefficient irrespective of type of construction project that was analyzed in their research. As a result, floor area and a combined Extent of Renovation/Mechanical-Electrical-Plumbing (MEP) work/Quality of Finishes factor will be utilized as the predictor variables in the model.

To develop a representative model for vertical construction projects, the following data are necessary:

- Data that convey project physical and constructability information, i.e. floor plans
- Total Project Cost data

This data comes from the aforementioned sources.

As documented in the previous literature review, several steps are involved in the development of a parametric cost estimating model. The process steps for building the model include:

- Cost model scope determination
- Data acquisition
- Data normalization
- Data analysis
- Model validation

Adhering to this progression and format for the model development enhances the probability of higher accuracy for generated cost predictions. As a first step, establishing the proper scope for the model facilitates accurate cost projections as the data need to be sourced from projects that are similar in nature. Within the university system, building renovations projects provide the most appropriate category of vertical construction with the most data and will therefore provide the basis for the parametric cost estimating model scope. Large new construction projects such as the UAA Engineering Building, the UAS Student Residence Hall, or the UAF Museum of the North will be excluded from the data input and model.

As cited in the previous literature review, the use of a statistical software package/platform facilitates the development of a parametric cost estimating model by providing a means to analyze the available data. After consideration of several options, Statgraphics Centurion 17 software will be used to analyze the data obtained from the various sources. The software will generate analysis tables and narratives, plots, and algorithms to use for the estimating model.

3.2 Data Acquisition and Preparation

Historical cost data and project documents were requested from the Directors of the three UA system branch facilities departments. No response to repeated requests was forthcoming from the UAS Director regarding the provision of data for the study. A meeting was held with the UAF Director and the cost data provided are included in the Appendices. No other data access, information, or construction documents were provided in response to repeated requests. Project data provided proved to be inaccurate with respect to floor areas attendant with some of the renovation projects. The UAA Director provided an office contact and raw cost data was provided in spreadsheet form for the period of fiscal years 2013-2016. No response was forthcoming regarding repeated requests for earlier cost data and construction documents for renovation projects. Additional requests for construction documents to perform model validation were provided no response.

Prior to developing the parametric cost estimating model, the project data obtained from the UA system sources and the online plans room must be organized and prepared for entry into the data analysis software package. This process involves the following steps:

- Data acquisition from UA System
- Organize cost data provided based on funding source/account (UAA data)
- Determine project square footage footprints from construction documents/floorplans
- Assign Extent of Renovation/Mechanical-Electrical-Plumbing (MEP) work/Quality of Finishes factors

- Normalize data with Cost Indices (Time)
- Normalize data with Location Factors
- Input project cost data
- Input project physical data factors(Floor Area Square Footage/Extent of Renovation/MEP work/Quality of Finishes)
- Generate final data file for analysis with Statgraphics Centurion 17

Available construction floor plans were analyzed with Autodesk AutoCAD® or Design Review® to quantify floor areas and make basic determinations about the scope of work. A sample floor plan from one of the projects used in the model is depicted below:

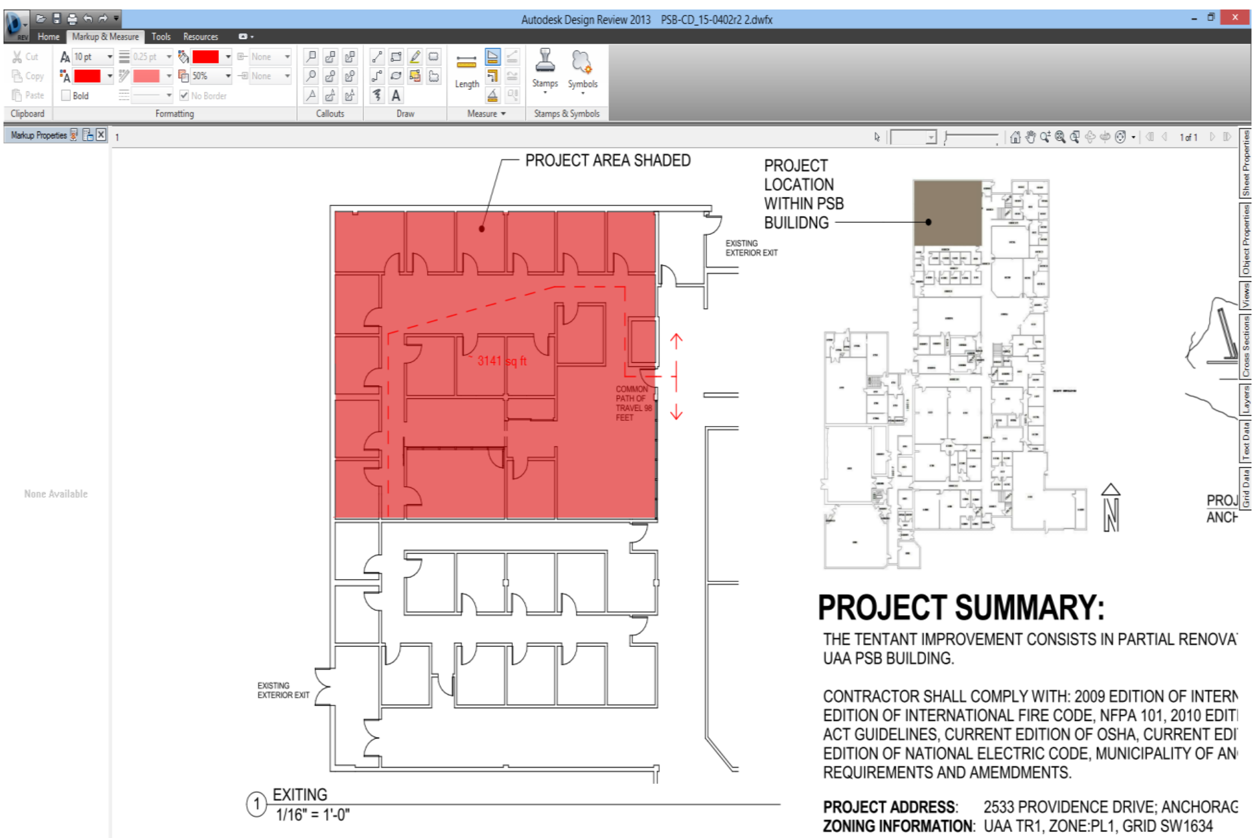

Figure 4. Project Floorplan with Quantified Square Footage - Autodesk Design Review®

Normalizing the data with respect to time is facilitated using inflation tables obtained from the Bureau of Labor Statistics/United State Department of Commerce (2016). Costs are indexed for inflation to the end of the fiscal year for single and multi-year funded projects. The index factors are provided in the table below:

Table 4. Inflation Index Factors (U.S. Bureau of Labor Statistics, 2016)

Year	Index Factor
2013	233.504
2014	238.343
2015	238.638
2016	241.038

Normalizing the data with respect to location is facilitated with the use of a location factor table obtained from the State of Alaska Department of Education. The location factor table is shown below:

Table 5. Alaska Location Factors (State of Alaska, Department of Education, 2012)

City - Borough - Region	Location Factor	Addition Above Base
Anchorage (Base)	100.00	0.0000
Bristol Bay Borough	128.70	0.2870
Dillingham City Schools	133.54	0.3354
Fairbanks	105.00	0.0500
Kenai Peninsula-Kenai/Soldotna	98.60	-0.0140
Kenai Peninsula-Homer Area	105.50	0.0550
Kodiak-Kodiak Island	112.40	0.1240
Lower Kuskokwim-Bethel	156.10	0.5610
Mat-Su Borough Schools-Palmer - Wasilla	99.00	-0.0100
Nome City Schools	156.10	0.5610
Northwest Arctic Schools-Kotzebue	150.18	0.5018
Valdez City Schools	109.30	0.0930

After costs are normalized with respect to location, project physical attributes must be discerned for entry into the software package. This process and accompanying strategy is discussed in the proceeding section of the study

3.3 Data Analysis Strategy

Multiple regression modeling will be a data analysis technique employed to derive the cost estimating relationship that is the basis of the parametric cost estimating model. According to Fox (2016),

> Regression analysis examines the relationship between a quantitative response variable, Y, and one or more explanatory variables, $X_1; \ldots ; X_k$. Regression analysis traces the conditional distribution of Y—or some aspect of this distribution, such as its mean—as a function of the X's.

This statistical technique can be used to analyze the relationship between a single dependent (criterion) variable and several independent (predictor) variables through use of the independent variables whose values are known to predict the single dependent value.

Total project cost (dependent/criterion) will be forecast based on project square footage an Extent of Renovation/MEP Factor/Quality of Finishes factor (independent/predictor) to obtain a model that will predict costs for upcoming projects. The model will provide an algorithm similar to the following form of Equation 2:

Cost = Constant + X(Square Footage) + Y(Extent of Renovation/MEP Factor/Quality of Finishes)

Total project cost and project square footage are interval data types and continuous variables. Extent of Renovation/MEP Factor/Quality of Finishes are ordinal data types and ranked variables.

Given the available data, a strategy to integrate the degree of renovation attendant with a given project, MEP work, and quality of finishes as ordinal variables into the model needs to be formulated and executed. In terms of general construction project knowledge, more space renovation is directly related to more extensive MEP work. The extent of these scopes of work was not discernible from the majority of the floor plans available for this study. With the unforeseen lack of definitive construction documentation for the majority of the projects, the strategy of combining the various scope of work factors into a single criteria attempts to address potential multicollinearity issues with the model. The results will be analyzed further along in the study to determine if this strategy may have worked in that regard. Additionally, Latief et al. (2013) indicate that utilizing stepwise multiple regression facilitates the recognition of multicollinearity in the variables selected for use in the model.

Total project cost based on the square footage of the renovation provides a guideline to establish a combined factor for these scopes of work. Based on project descriptions, costs, square footage, and available floor plans, the strategy employed will combine these ranked variables for purposes of this study. These variables will be assigned values from 1 to 6 as outlined below based on available data and floor plans:

- 1: Finishes Only/Minimal-No MEP Work
- 2: Moderate Space Renovation/Minor MEP Work/Typical Quality Finish

- 3: Moderate-Substantial Space Renovation-Core Alteration/Moderate MEP Work/ Typical Quality Finish
- 4: Substantial Space Renovation-Expansion-Core Alteration/Moderate-Significant MEP Work/ Typical Quality Finish and Specialty Equipment/Technology
- 5: Extensive Space Renovation-Expansion-Core Alteration/Significant MEP Work/ Typical Quality Finish and Specialty Equipment/Technology
- 6: Extensive Space Renovation Expansion-Core Alteration/Significant MEP Work /High Quality Finishes

Chan and Park (2005) utilized a ranking scale for numerous elements of construction that were subsequently integrated into a parametric estimating model. These elements were grouped into three general categories shown below:

- Project design, intricacy, and duration
- Design and management skill of the project team
- Contractor's experience and skill

As previously mentioned, the statistical analysis software package Statgraphics Centurion 17 will be used to perform the data analysis and obtain a Cost Estimating Relationship algorithm to derive the parametric cost estimating model. Stepwise multiple regression and general linear model analysis modes will be utilized to generate algorithms and evaluate the data with various statistical tests and against various metrics. Additionally, the data will be transformed with natural logarithms to determine if the data fit better to a non-linear relationship.

Bajaj et al. (2002) developed a strategy and methodology to build and maintain a parametric estimating model for construction design costs. The strategy may be extended to general construction costs. The study indicates that a historical database of costs acts as the cornerstone of the model. As jobs are executed and completed, new data from recent projects, data preparation and normalization factor updates, and statistical analysis performed on the new information is regularly processed and integrated into the model to provide a high probability of accuracy for predicted results. A flowchart of the methodology is depicted below:

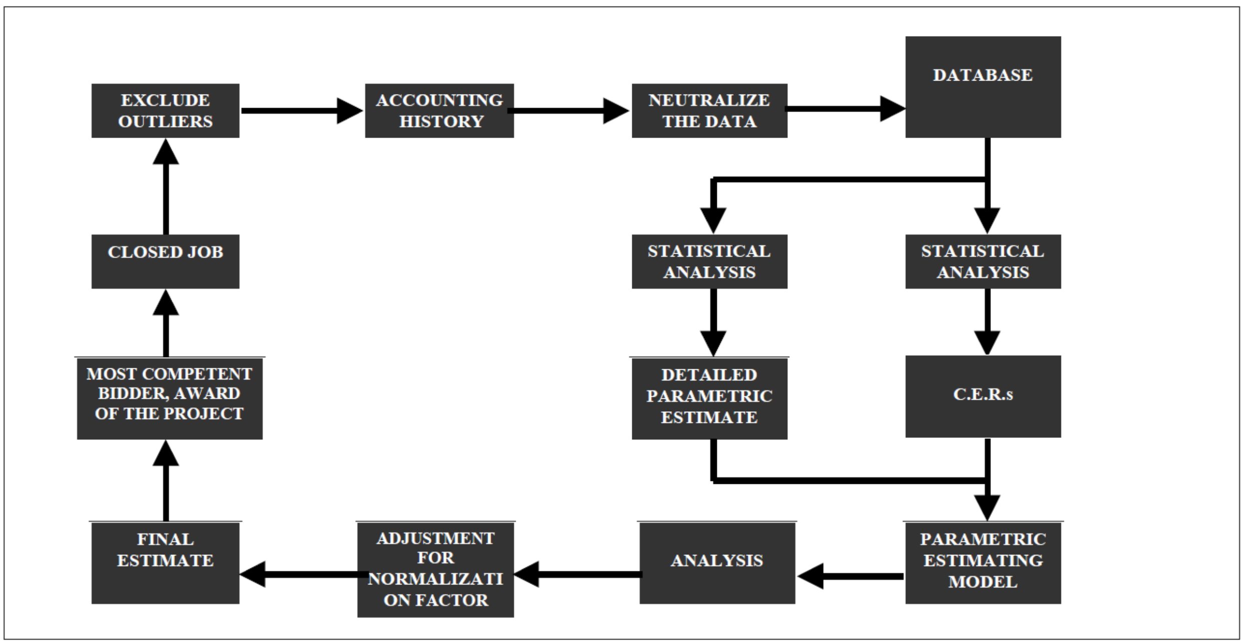

Figure 5. Parametric Cost Estimating Process for Construction Project Design Costs (Bajaj et al. 2002).

Large international corporations have determined that developing and maintaining parametric cost estimating models is a sound strategy for planning and budgeting. With buildings and operations around the globe, Eastman Kodak utilizes a well-developed model to screen proposed projects for feasibility and potential budgeting. According to Arioli and Masi (2002), the model depicted below is transparent, comprehensive, and simple to use.

EK PARAMETRIC SQUARE FOOT COST ESTIMATING PROGRAM (Strategic)

Project:	SAMPLE PROJECT - BUILDING FOR XYZ MACHINE	Date:	11/7/01
Location:	ROCHESTER NEW YORK	Building:	NEW
Est. by:	ARIOLI & MASI	Customer:	AACE INTERNATIONAL

ENTER VALUES FOR THE FOLLOWING PARAMETERS:

Usable Floor Area (square feet):	30,000	% Office:	10%	% Heated:	90%
Avg. Floor to Floor Height (feet):	18	% Wet Lab:	0%	% Cooled:	10%
Number of Floors:	3	% Dry Lab:	0%	#Corners:	4

ENTER VALUES FOR THE FOLLOWING FACTORS:

Location Code:	0	(0=Means, Roch=1, KPW=2, KPE=3)
Labor Productivity Factor:	0	(0=Greenfield, 1=Existing Facility
Sub Structure:	3	(0 to10, v. light=0, Typ=3, v. hvy=10)
Super Structure:	3	(0 to10, v. light=0, Typ=3, v. hvy=10)
Fireproofing Coverage/Rating Index Factor *:	0	(0 to10, None=0, Typ=3, Max.=10)
Finish Quality Index Factor - Exterior *:	3	(1 to 10, Means=3, Avg. KP=7)
Finish Quality Index Factor - Interior *:	3	(1 to 10, Means=3, Avg. KP=7)
Services Quality Index Factor - Mechanical *:	3	(1 to 10, Means=3, Avg. KP=7)
Services Quality Index Factor - Electrical *:	3	(1 to 10, Means=3, Avg. KP=7)
General Adjustment Factor *:	1.00	(relative multiplier, No Change=1.00)
Project Year 2001 — Project Year Factor	0.0%	(escalation factored @ 3% / year)

*The cost impacts of Quality Factor values that exceed "Commercial" basis are shown in the Extra column below

CSI ACCT.	fact.	Base $	*Extra* *	Escalation	Total $	$/SF	% of Tot $
1 Foundations	1.00	73,780	0	0	73,780	$2.46	4.7%
2 Substructure	1.00	65,450	0	0	65,450	$2.18	4.2%
3 Superstruct.	1.00	435,540	0	0	435,540	$14.52	27.9%
4 Extr. Closure	1.00	186,830	0	0	186,830	$6.23	12.0%
5 Roofing	1.00	55,930	0	0	55,930	$1.86	3.6%
6 Intr. Constr.	1.00	170,170	0	0	170,170	$5.67	10.9%
7 Elevators	1.00	54,740	0	0	54,740	$1.82	3.5%
8 Mechanical	1.00	242,760	0	0	242,760	$8.09	15.6%
9 Electrical	1.00	140,420	0	0	140,420	$4.68	9.0%
11 Specialties	1.00	59,500	0	0	59,500	$1.98	3.8%
12 Site Work	1.00	0	0	0	0	$0.00	0.0%
User Add	1.00	0	0	0	0	$0.00	0.0%
Admin/Eng	*5%*	74,000	0	0	74,000	$2.47	4.8%
POINT TOTALS:		1,559,120	0	0	1,559,120	$51.97	100.0%
(above includes OH&P)			Contingency:	15%	234,000		
BUILDING COSTS to FUND (50% conf. of underrun):					1,793,120	$59.77	
Range: 90% confidence that actual			Low:	-30%	1,091,000	$36.37	
will fall within this range:			High:	50%	2,339,000	$77.97	

Notes:

Note: Base cost are for 2001
All costs include an allowance for General Requirements (OH&P)

Figure 6. Eastman Kodak Parametric Cost Estimating Model Data Sheet (Arioli and Masi, 2002).

Developing and maintaining parametric cost estimating models for institutions that frequently need to update and build new facilities can provide benefits for planning, budgeting, and screening alternative projects were limited resources are available to upgrade or replace existing buildings. This study employs ideas and strategies for developing a model based on a survey and examination of pertinent literature and sources.

According to Petroutsatou, Lambropoulos, and Pantouvakis (2006), a certain proportion of the sample projects for a parametric cost estimating model should be randomly selected as an ex ante set for model validation. The principle reason for validating a parametric cost estimating model is to instill confidence in the project stakeholders – especially the owners – with respect to the veracity of the results provided by the model within the expected range of accuracy. They suggest that approximately 25% of the project sample be excluded from the model for validation purposes. This provides a robust check set of projects to compare with results generated from the model.

Due to a lack of available project construction documentation and cost data, this percentage of sample projects dedicated to model validation is not practical for this study. To maintain as many projects in the model as possible and maximize potential statistical significance, only two projects will be held out of the model generated as a part of this study to be used as validation projects. 50 projects are included in the model for analysis as demonstrated in the upcoming section.

Chapter 4 Data Analysis and Modeling

4.1 Statistical Analysis of Data

The multiple regression technique proposed to analyze the project data will be implemented with Statgraphics Centurion 17. A stepwise regression process applied to the data will be complemented with a General Linear Model analysis. Interval data will be transformed logarithmically to determine if the transformation provides a better data fit.

An introductory depiction of the data will provide an indication of the data points of the project costs entered into the model. Scatter plots of the dependent variable (Final Cost) versus the independent variables (Square Footage – Reno/Finishes/MEP) are provided below:

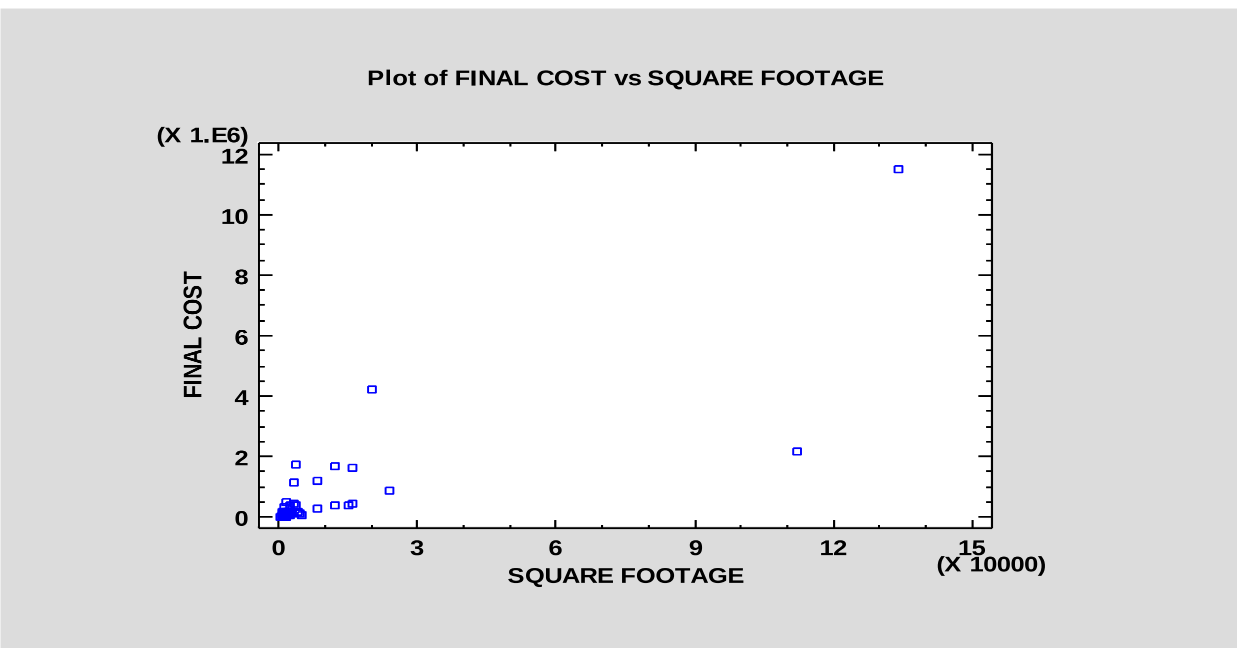

Figure 7: Scatterplot of Final Project Cost versus Square Footage

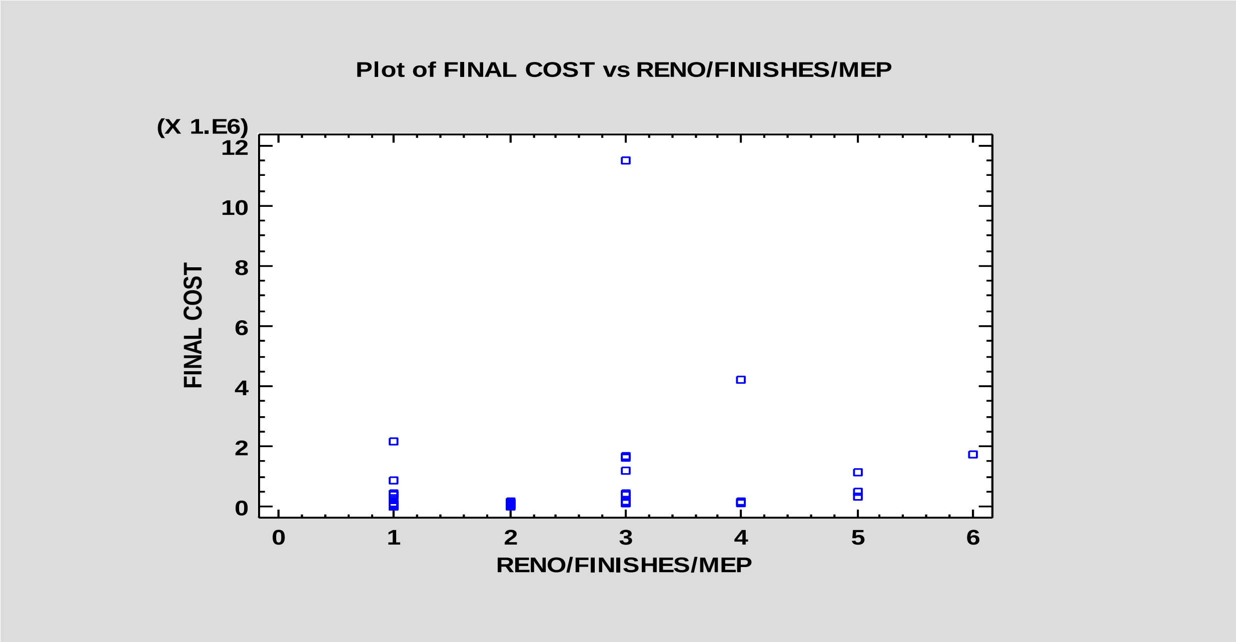

Figure 8: Scatterplot of Final Project Costs versus Reno/Finishes/MEP

As depicted by the plots, the majority of the projects are at the lower cost end. Additionally, most of the projects have Reno/Finishes/MEP scopes of work in the low to moderate category. The similarity of the project with respect to cost and scope of work will likely provide a model with reasonable correlation of the dependent and independent variables.

4.2 Multiple Regression – Base Data

According to Keller (2012), the application of multiple regression to a data set involves a general two-step process. Initially, it is important to determine how well the model fits the data. If the model fit is questionable or of low quality, another model needs to be employed to better fit the data. After a quality fit is achieved, the coefficients of regression – can be examined. The general form of the multiple regression equation is provided below (Equation 3):

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k$$

where y is defined as the dependent variable; b is defined as the regression coefficients; x is defined as the independent variable; and k is the quantity of independent variables.

Secondly, the regression coefficients can be examined and applied to predict values of the dependent variable after a good fit to the data is found.

As previously discussed, total project cost will be predicted based on project square footage and Extent of Renovation/MEP Factor/Quality of Finishes factor to obtain a model that will forecast costs for upcoming projects. The model will provide a cost estimating relationship algorithm shown below (Equation 4):

$$y = b_0 + b_1x_1 + b_2x_2$$

where y is Project Cost; b_0 is the Regression Constant; b_1 is the Regression Coefficient for Project Square Footage; x_1 is Project Square Footage; b_2 is the Regression Coefficient for Extent of Renovation/MEP Factor/Quality of Finishes factor; x_2 is the Extent of Renovation/MEP Factor/Quality of Finishes factor.

First, the data set will be analyzed with a multiple regression procedure from Statgraphics. Tables of metrics and plots are generated based on the analysis. Descriptions of the values are provided proceeding the tables and plots. The various statistics generated from the analysis are provided in the following tables:

Table 6. Statistics Derived from Multiple Regression Procedure

		Standard	*T*	
Parameter	*Estimate*	*Error*	*Statistic*	*P-Value*
CONSTANT	-741550.	263164.	-2.81783	0.0071
SQUARE FOOTAGE	59.7981	5.21723	11.4617	0.0000
RENO/FINISHES/MEP	366932.	97480.8	3.76414	0.0005

Table 7. Analysis of Variance for Multiple Regression Procedure

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Model	1.10509E14	2	5.52544E13	70.68	0.0000
Residual	3.67424E13	47	7.81753E11		
Total (Corr.)	1.47251E14	49			

Table 8. Unusual Residuals for Multiple Regression Procedure

		Predicted		*Studentized*
Row	*Y*	*Y*	*Residual*	*Residual*
37	1.1485E7	8.38182E6	3.10318E6	8.66
41	2.15306E6	6.33018E6	-4.17712E6	-13.28
43	4.2226E6	1.93087E6	2.29173E6	2.87

Regression statistics are provided below:

- R-squared = 75.0478 percent
- R-squared (adjusted for d.f.) = 73.986 percent
- Standard Error of Est. = 884168

The equation of the fitted model is provided below (Equation 5):

FINAL COST = -741550 + 59.7981*SQUARE FOOTAGE + 366932*RENO/FINISHES/MEP

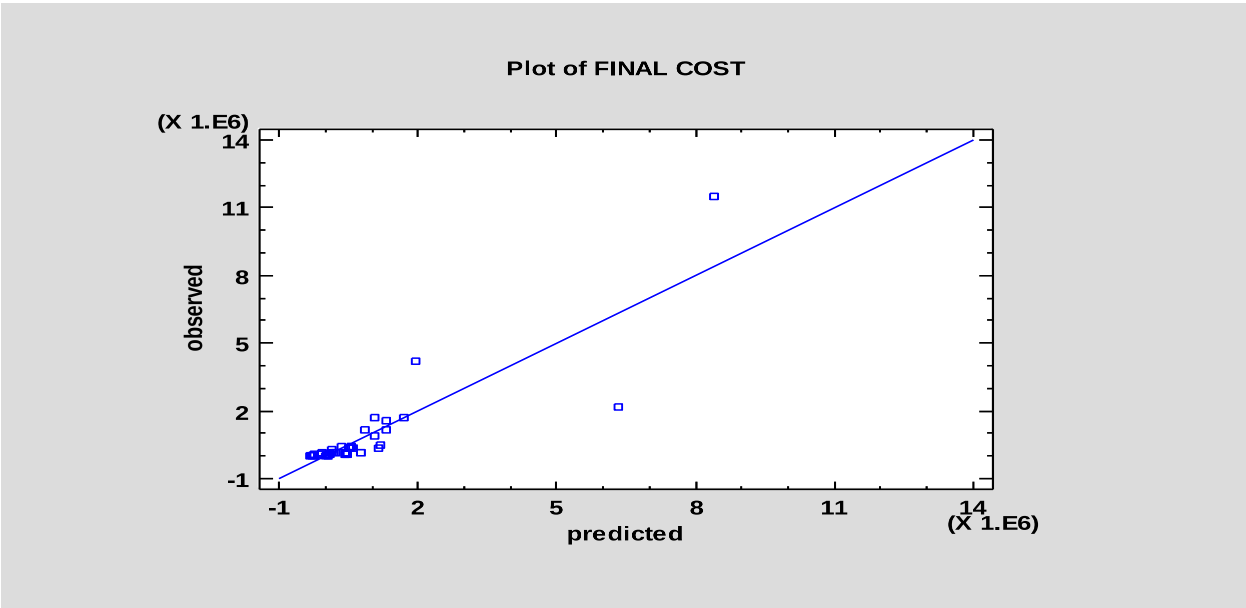

Figure 9: Plot of Final Cost – Observed Costs versus Predicted Cost

Column 2 values provided in Table 4 are the regression coefficients in the equation of the fitted model representing the cost estimating relationship. The standard error values found in Column 3 indicate the disparity between the input data and the values generated with the regression analysis and provides a guide to how well the model fits the data. The t-statistic and p-values are metrics ascribed to a test of the validity of the assumption that the dependent and independent variables are related. Higher values of the t-statistic and attendant lower p-values indicate this relationship is statistically significant at an established confidence level – usually 95%. With respect to the analysis of variance (ANOVA) table, the sum of squares column show the values related to the errors between the data and the estimates. The mean square error is this value adjusted for the sample size. The F-ratio and p-values in the ANOVA table are comparable to the t-statistic and its related p-value. The R-squared values represents a measure of how much variation in the dependent variable is explained by the independent variables. Values closer to 1 indicate a high degree of correlation between the variables.

The plot shows a fitted line through the data based on the results of the regression analysis. The closer the data points are to the fitted line, the better the correlation between the data and the fitted line model. An analysis of the results of the multiple regression procedure are provided below in Section 4.4.

4.3 Multiple Regression/General Linear Model – Transformed Data

The next regression run is performed on the data set transformed with the application of natural logarithms applied to the interval data. First a General Linear Model will be run on the data set. Statistics for a General Linear Model with logarithm transformed project data is provided below:

Table 9: Analysis of Variance for LN(Cost)

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	121.771	6	20.2951	222.48	0.0000
Residual	3.92254	43	0.0912218		
Total (Corr.)	125.693	49			

Table 10: Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
RENO/FINISHES/MEP	42.5522	5	8.51043	93.29	0.0000
LN(SqFt)	76.3576	1	76.3576	837.06	0.0000
Residual	3.92254	43	0.0912218		
Total (corrected)	125.693	49			

Table 11: Unusual Residuals

		Predicted		Studentized
Row	Y	Y	Residual	Residual
11	9.56425	10.3518	-0.787551	-2.93
12	8.84251	9.82717	-0.984664	-3.95

Table 12: 95% Confidence Intervals – V.I.F. Statistic for Multicollinearity

		Standard			
Parameter	*Estimate*	*Error*	*Lower Limit*	*Upper Limit*	*V.I.F.*
CONSTANT	4.26194	0.297606	3.66176	4.86212	
RENO/FINISHES/MEP	-1.79185	0.0919904	-1.97737	-1.60634	1.22636
RENO/FINISHES/MEP	-0.933926	0.105196	-1.14607	-0.721778	1.21311
RENO/FINISHES/MEP	-0.187196	0.0966918	-0.382194	0.00780222	1.19093
RENO/FINISHES/MEP	0.559656	0.158343	0.240326	0.878987	1.07743
RENO/FINISHES/MEP	0.982777	0.158724	0.662679	1.30287	1.08261
LN(SqFt)	1.06786	0.0369093	0.993421	1.14229	1.18778

Regression statistics are provided below:

- R-squared = 96.8793 percent
- R-squared (adjusted for d.f.) = 96.4438 percent
- Standard Error of Estimate = 0.302029

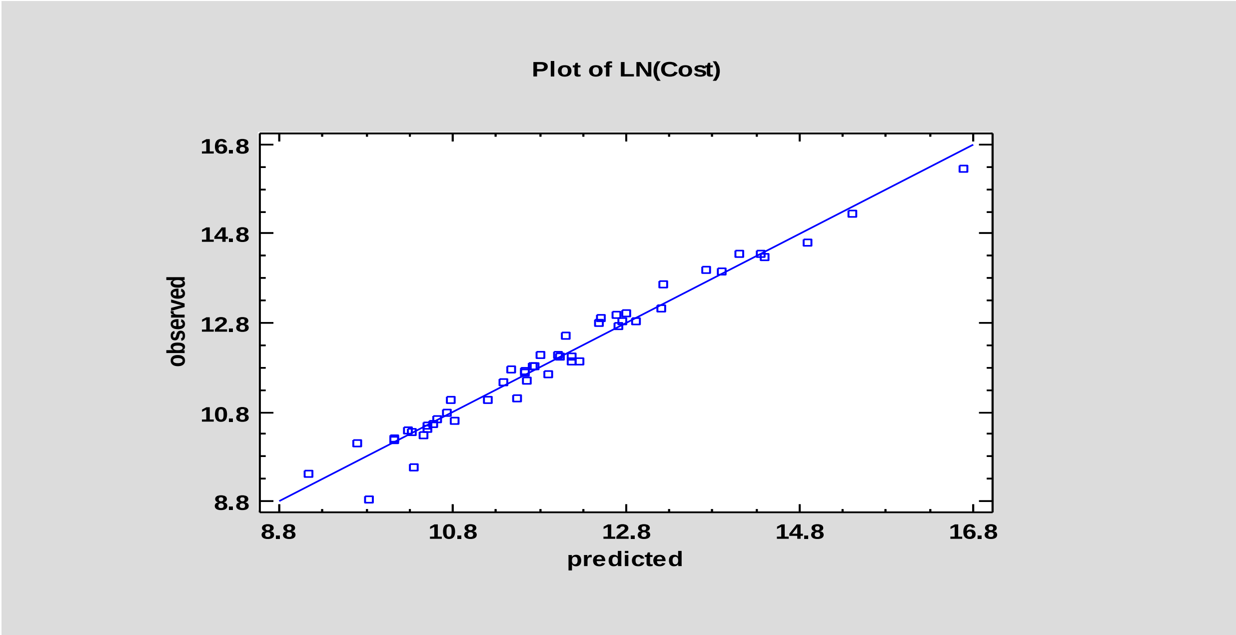

Figure 10: Plot of LN(Final Cost) – Observed Costs versus Predicted Cost

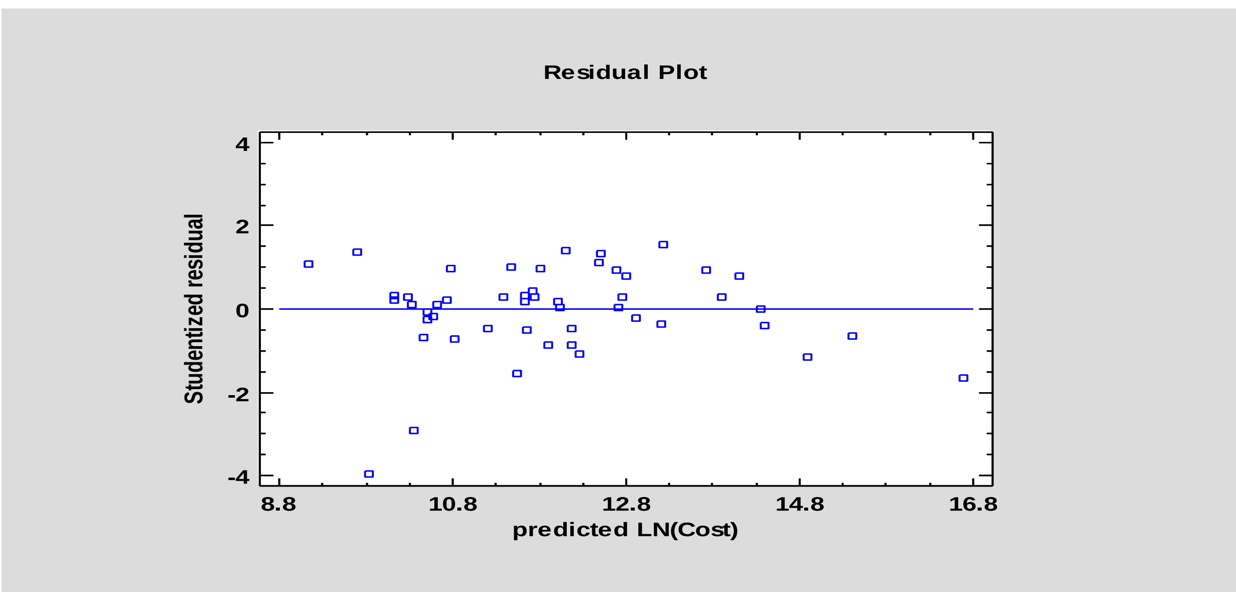

Figure 11: Residual Plot of predicted LN(Final Cost)

The values found in Tables 7 and 8 are described above. Table 9 indicates the unusual errors or residuals found related to specific data points. Values of ± 2 are flagged as unusual. Table 10 provide the variance inflation factor (VIF) values for the independent variables integrated into the model. The lower the values, the less likelihood that the independent variables demonstrate multicollinearity. The residual plot of Figure 14 is provided to examine the model for constancy in the error variable. Homoscedasticity is the term that indicates the occurrence or condition of constancy in the variance of the error variable. The more prominent this characteristic, the more valid the model with respect to this metric. The residuals should be evenly dispersed above and below the x-axis on the plot, and if the unusual residuals are discounted, this condition is essentially met. An analysis of the results of the General Linear Model procedure are provided below in Section 4.4.

The next regression run – a stepwise regression process - is performed on the data set transformed with the application of natural logarithms applied to the interval data. Statistics for the regression process with logarithm transformed project data is provided below:

Table 13: Statistics Derived from Multiple Regression-Transformed Data

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1.90437	0.299437	6.35982	0.0000
LN(SqFt)	1.059	0.0350999	30.1711	0.0000
RENO/FINISHES/MEP	0.715181	0.0344636	20.7518	0.0000

Table 14: Analysis of Variance-Transformed Data

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	121.12	2	60.5601	622.40	0.0000
Residual	4.57317	47	0.0973014		
Total (Corr.)	125.693	49			

Table 15: Unusual Residuals-Transformed Data

		Predicted		Studentized
Row	Y	Y	Residual	Residual
11	9.56425	10.4359	-0.871659	-3.11
12	8.84251	9.91563	-1.07312	-4.10

Regression statistics are provided below:

- R-squared = 96.3616 percent
- R-squared (adjusted for d.f.) = 96.2068 percent
- Standard Error of Estimate = 0.311932

The equation of the fitted model is provided below (Equation 6):

LN(Cost) = 1.90437 + 1.059*LN(SqFt) + 0.715181*RENO/FINISHES/MEP

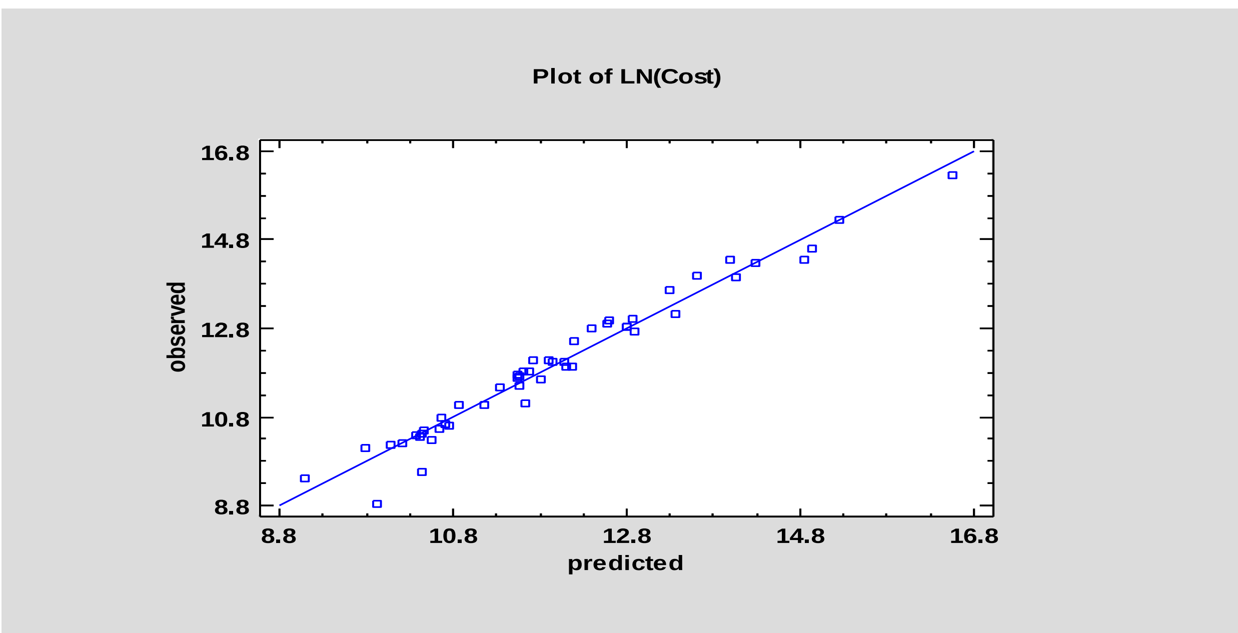

Figure 12: Plot of LN(Final Cost) – Observed Costs versus Predicted Cost

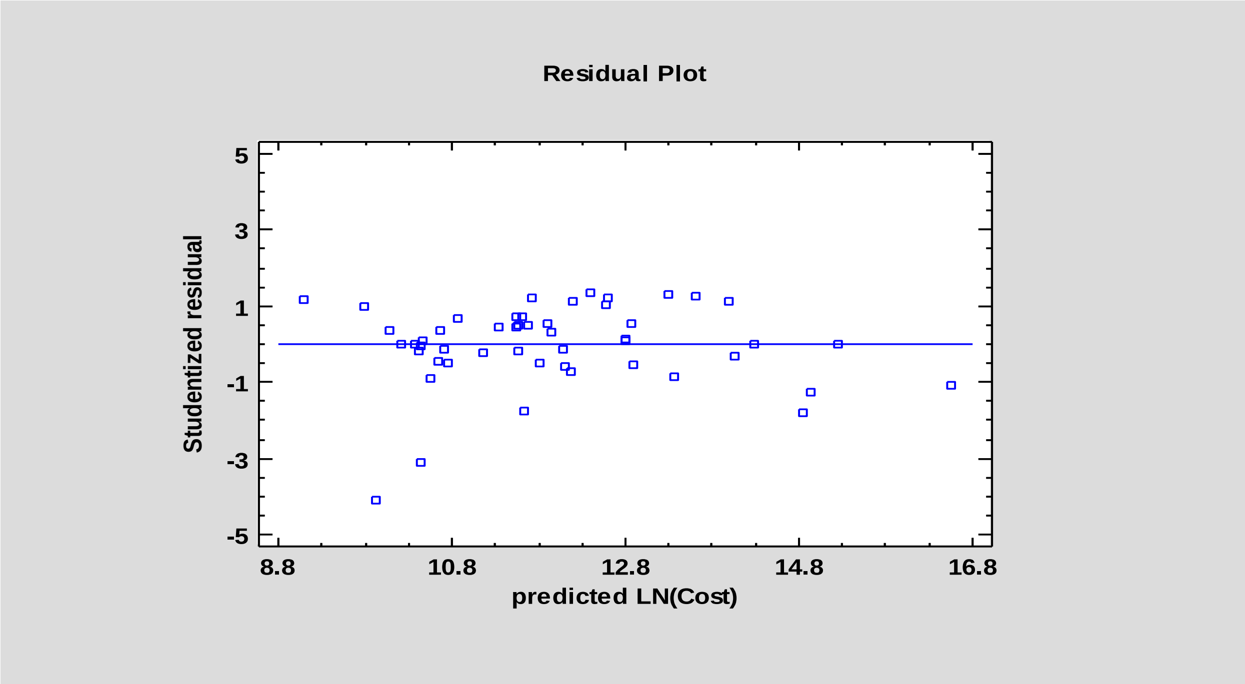

Figure 13: Residual Plot of Predicted LN(Final Cost)

The values provide in Tables 13 and 14 and the plots provided in Figures 15 and 16 are equivalent to what was explained in the previous regression and General Linear Model runs.

4.4 Analysis of Results

For the first multiple regression run, the results indicate a reasonable fit – especially in the lower cost range. The coefficient of determination – R^2 – indicates that approximately 73% of the variability in project cost is defined by the square footage and Reno/Finishes/MEP factor. Since the P-values in the Statistics and ANOVA tables for Total Cost is less than 0.05, there is a statistically significant relationship between Total Cost and the predictor variables at the 95.0% confidence level. The high F value indicates that most of the variability in the dependent variable is explained by the equation of the fitted model. Consequently, the model has validity. Two unusual residuals are present and this indicates issues with the error between the data and the estimate in the project cost predictions.

With a transformation of the data with natural logarithms, the General Linear Model results indicate a robust fit across the range of projects. The coefficient of determination – R^2 – indicates that approximately 96% of the variability in project cost is defined by the square footage and Reno/Finishes/MEP factor. Since the P-values in the Statistics and ANOVA tables for Total Cost is less than 0.05, there is a statistically significant relationship between Total Cost and the predictor variables at the 95.0% confidence level. The high F value indicates that most of the variability in the dependent variable is explained by the equation of the fitted model. Consequently, the model has significant validity. Two unusual residuals are present and this indicates minor issues with the error in the project cost predictions. The values of these residuals are close to ± 2, so the data points are suspect, but would not be considered to have a large effect on the model validity. Low VIF values denote lack of multicollinearity between the independent variables of project square footage and Reno/Finishes/MEP factor. The strategy of combining these scope of work factors into one overarching factor appears to have been effective for the transformed General Linear Model.

After transforming the data with natural logarithms, the results of the multiple regression analysis indicate a robust fit across the range of projects. The coefficient of determination – R^2 – indicates that approximately 96% of the variability in project cost is defined by the square footage and Reno/Finishes/MEP factor. Since the P-values in the Statistics and ANOVA tables for Total Cost is less than 0.05, there is a statistically significant relationship between Total Cost and the predictor variables at the 95.0% confidence level. The high F value indicates that most of the variability in the dependent variable is explained by the equation of the fitted model.

Consequently, the model has significant validity. Two unusual residuals are present and this indicates minor issues with the error in the project cost predictions. The values of these residuals are close to ± 2, so the data points are suspect, but would not be considered to have a large effect on the model validity.

One project was available to check the model due to requested data not being provided by UA system personnel. After the initial data was received and up to the last several days prior to report completion, provision of additional data from UA system personnel was ostensibly forthcoming. Data beyond what was provided after the first cost spreadsheets were obtained at the beginning of the Fall Semester never materialized despite repeated requests to all UA system branches personnel.

Utilizing the equation obtained from the regression model with the logarithmically transformed data, the following project data will be used to check the model:

Location/Project Name: Anchorage – AHS Renewal Phase 3 and 4

Date of Project: 2014 > Index factor for year is 1.0219868

Square Footage: ~ 12,000

Reno/Finishes/MEP factor assigned: 4

Project Cost with adjustments for design @ 5%: $2,642,616

Predicted Cost with algorithm: $2,450,795

The predicted cost is well within the ± 30% range base on a Class 4 estimate that was depicted previously in the study. However, more project data is required to validate the model to ensure that the Cost Estimating Relationship is valid. A check with two other projects included in the model – although not appropriate for model validation provide the following results:

Location: Anchorage – RH 110 Renovation

Square Footage: ~ 1,899

Reno/Finishes/MEP factor assigned: 2

Project Cost: $96,217

Predicted Cost with algorithm: $83,217

Location: Anchorage – RH 117 Renovation

Square Footage: ~ 2,380

Reno/Finishes/MEP factor assigned: 2

Project Cost: $123,078

Predicted Cost with algorithm: $105,698

With considerably more data a better model could be developed that would consistently predict project costs within the ± 30% accuracy range expected for a Level 4 parametric cost estimate.

Although the regression and General Linear Models yielded quality results with respect to goodness-of-fit and a cursory check for validation, the accuracy of the model with the logarithm-transformed data will be questionable for larger renovation projects. The slope of the curve $y = \ln(x)$ increases drastically for values approaching double digits. A different type of data transformation – likely a polynomial transformation – would provide a better model for larger square footage projects.

The overwhelming use of "like-kind" projects as data for the model appears to have been a sound strategy. According to Kan (2002), the use of dissimilar projects with different end uses as data for a parametric cost estimating model enhances the probability of generating inaccurate or invalid results. Fortunately, the available data and the research used to perform this study conformed to this strategy.

\

Chapter 5 Conclusions

For institutions like the University of Alaska system, developing, utilizing, and maintaining a parametric cost estimating model for system-wide construction renovation projects would be a wise choice. After the initial resources on working through and preparing the cost data and cataloging the construction documentation were expended, using and maintaining the model would be simple and efficient. With a few keystrokes and in less than a minute, screening estimates could be generated for projects statewide and apportioning budget resources could be commence with the confidence that the numbers would provide a reasonable guideline for anticipated costs. Managers in the statewide system, regents, or member of or affiliated with the legislature could use the model to establish the economic feasibility of renewal programs for buildings owned or leased by the University of Alaska.

Based on the input received from UA system personnel, unit cost estimates – which require more resources and time than a parametric estimate as depicted in this study - are generated for the majority of potential renovation and remodel projects. Regardless, the enhanced ability to formulate Class 4 cost estimates at the system or even state government level for funding baskets of projects would have significant value.

Given the challenging fiscal times faced by the State of Alaska, any strategy implemented that would facilitate better planning and distribution of resources for less time and money needs to be considered. This study is the upshot of the idea that the State of Alaska and UA system could save money and obtain improved guidance on expending effort and resources.

With the idea of engaging in this study being in mind for some time, one item stands out – the issues that have been encountered obtaining the data for the study. Hopefully, at some point those in positions of authority may consider this idea and model for the UA system something worth pursuing and at some point actually integrating into the building renovation planning program. The author of this study knows it would be a sound investment in time and resources. This is the significant contribution of this study – providing management a tool that adds value to the activities attendant with overseeing a large state-funded higher educational system.

References

AACE International. (1997). *Recommended Practice 17R-97. Cost Estimate Classification*, 6

AbouRizk, S. M., Babey, G. M., & Karumanasseri, G. (2002). Estimating the cost of capital projects: An empirical study of accuracy levels for municipal government projects. *Canadian Journal of Civil Engineering, 29*(5), 653–661

Adel, K., Elyamany, A., Belal, A. M., & Kotb, A. S. (2016). Developing Parametric Model for Conceptual Cost Estimate of Highway Projects. *International Journal of Engineering Science, 6*(7), 1728-1734.

Ahn, J., Kim, H.-J., Yong-Chil, S., & Chang-Taek, H. (2012). The attribute impact concept: Applications in case-based reasoning and parametric cost estimation. *Automation in Construction*, 25, 72–81. doi:http://dx.doi.org.proxy.consortiumlibrary.org/10.1016/j.autcon.2014.03.011

Akintoye, A. (2000). Analysis of factors influencing project cost estimating practice. *Construction Management & Economics, 18*(1), 77-89.

Amos, S. (Ed.) & Dysert, L.R. (2010). Estimating. *Skills and Knowledge of Cost Engineering, 5th Edition* (9.1-9.34). Morgantown, WV: AACE International.

Arioli, D. L. & Masi, J. G. (2002). Development and Maintenance of a Parametric Building Estimating System. *2002 AACE International Transactions*, EST.10, 10.1-10.5

Bajaj, A., Gransberg, D. D., & Grenz, M. D. (2002). Parametric estimating for design costs. *2002 AACE International Transactions*, ES.1, 81-86.

Bureau of Labor Statistics, U.S. Department of Commerce (2016). Consumer Price Index - All Urban Consumers. Retrieved from http://data.bls.gov/cgi-bin/srgate

Chan, S. L., & Park, M. (2005). Project cost estimation using principal component regression. *Construction Management and Economics, 23*(3), 295–304. doi:http://dx.doi.org.proxy.consortiumlibrary.org/10.1080/01446190500039812

Davis, James J. (1998). Parametric Estimates Made Easy. *1998 AACE International Transactions*, 01.1-01.10

Department of Defense (1999). Parametric Estimating Handbook. Second Edition. Retrieved from
http://www.ispa-cost.org/PEIWeb/newbook.htm

Department of Defense (2000). Contract Pricing Reference Guides. Retrieved from http://www.acq.osd.mil/dpap/contractpricing/vol2chap7.htm#7.0

Dysert, L. R. (2005). So You Think You're an Estimator? *2005 AACE International Transactions*, 01.1-01.6

Fox, J. (2016). *Applied Regression Analysis and Generalized Linear Models, Third Edition.* Thousand Oaks, CA: SAGE Publications.

Ji, S. H., Park, M., & Lee, H. S. (2010). Data Preprocessing–Based Parametric Cost Model for Building Projects: Case Studies of Korean Construction Projects. *Journal of Construction Engineering and Management*, *136*(8), 844-853.

Jrade, A., & Alkass, S. (2007). Computer-integrated system for estimating the costs of building projects. *Journal of Architectural Engineering*, *13*(4), 205-223.

Kan, P. (2002). *Parametric Cost Estimating Model for Conceptual Cost Estimating of Building Construction Projects* (PhD. Thesis). University of Texas, Austin TX.

Keller, G. (2012). *Statistics for Management and Economics, Ninth Edition.* Mason, OH: Cengage Learning.

Kim, H. J., Seo, Y. C., & Hyun, C. T. (2012). A hybrid conceptual cost estimating model for large building projects. *Automation in Construction*, 25, 72-81.

Kim, G., Shin, J., Kim, S. and Shin, Y. (2013). Comparison of School Building Construction Costs Estimation Methods Using Regression Analysis, Neural Network, and Support

Vector Machine. *Journal of Building Construction and Planning Research*, 1, 1-7. doi:10.4236/jbcpr.2013.11001

Kwak, Y. H., & Watson, R. J. (2005). Conceptual estimating tool for technology-driven projects: exploring parametric estimating technique. *Technovation, 25*(12), 1430-1436.

Lamboglia, E., Gaudenzi, P., & Joumier, H. (2008). Non-linear and multivariate regressions for space engineering parametric cost models. *Cost Engineering, 50*(8), 14-21. Retrieved from http://search.proquest.com.proxy.consortiumlibrary.org/docview/220457775?accountid=14473

Larson, P.D. (2002). Conceptual Estimating. *2002 AACE International Transactions,* EST.07, 07.1-07.8

Latief, Y., Wibowo, A., & Iswara, W. (2013). Preliminary cost estimation using regression analysis incorporated with adaptive neuro fuzzy inference system. *International Journal of Technology,* 1, 63-72.

Ling, F., Chan, S., Chong, E., and Ee, L. (2004). Predicting Performance of Design-Build and Design-Bid-Build Projects. *Journal of Construction Engineering and Management, 10*(1061)/(ASCE)0733-9364(2004)130:1(75), 75-83

Lowe, D. J., Emsley, M. W., & Harding, A. (2006). Predicting construction cost using multiple regression techniques. *Journal of Construction Engineering and Management, 132*(7), 750-758.

Melin, J. B. (1994). Parametric Estimation. *Cost Engineering. 36*(1) 19–24. Retrieved from http://search.proquest.com.proxy.consortiumlibrary.org/docview/220468012?accountid=14473

Meyer, R. E. & Burns, J. T. (1999). Facility parametric cost estimating. *Proceedings, Transactions of the American Association of Cost Engineers, 43rd Annual Meeting*, Denver, EST.02, 1-6.

Oberlender, G. D. & Trost, S. M. (2001). Predicting Accuracy of Early Cost Estimates Based on Estimate Quality. *Journal of Construction Engineering and Management, 127*(3). 173-182.

Parker, D. E. (2014). *Parametric Cost Modeling for Buildings*. New York, NY: Routledge Ltd.

Petroutsatou, C., Lambropoulos, S., & Pantouvakis, J. P. (2006). Road tunnel early cost estimates using multiple regression analysis. *Operational Research, 6*(3), 311-322.

Serpell, A. F. (2005). Improving conceptual cost estimating performance. *2005 AACE International Transactions,* ES131-ES136. Retrieved from http://search.proquest.com.proxy.consortiumlibrary.org/docview/208176262?accountid=14473

Shin, Y. (2015). Application of Boosting Regression Trees to Preliminary Cost Estimation in Building Construction Projects. *Computational Intelligence and Neuroscience*, 2015, 149702. doi.org/10.1155/2015/149702

Sonmez, R. (2008). Parametric range estimating of building costs using regression models and bootstrap. *Journal of Construction Engineering and Management, 134*(12), 1011-1016.

State of Alaska, Department of Education. (2012). *Program Demand Cost Model for Alaskan Schools.* Retrieved from https://education.alaska.gov/facilities/pdf/cost_model_instructions.pdf

Trost, S. M., & Oberlender, G. D. (2003). Predicting accuracy of early cost estimates using factor analysis and multivariate regression. *Journal of Construction Engineering and Management, 129*(2), 198-204.

Watson, R., & Kwak, Y. H. (2004). Parametric estimating in the knowledge age: Capitalizing on technological advances. *In IAMOT 2004 13th International Conference on Management of Technology.* Washington, DC, 1-11.

Whiteside II, J. D. (2004). Developing Estimating Models. *Cost Engineering, 46*(9), 23.

Appendix A

Master Project Table

Year	Location	Project	Final Adjusted Cost	Square Footage	Combined Impact - Reno/MEP
2013	Anchorage	UAA RH110 Renovation			
2014	Anchorage	UAA RH110 Renovation			
			$96,217.22	1899	2
2013	Anchorage	UAA RH101 Renovation			
2014	Anchorage	UAA RH101 Renovation			2
			$137,632.45	2656	
2013	Anchorage	UAA RH117 Renovation			
2014	Anchorage	UAA RH117 Renovation			2
			$123,078.32	2380	
2013	Anchorage	RH 105 DSS Office Improvements	$24,136.42	871	1
2013	Anchorage	CoH PSB 124 A-D Renovations			
2014	Anchorage	CoH PSB 124 A-D Renovations			1
			$129,459.01	4593	
2013	Anchorage	7th & A 205 Renovation	$33,637.39	823	2
2013	Anchorage	SSB 107 ITS Renovations			
2015		SSB 107 ITS Renovation			
			$36,009.20	834	2
2013	Anchorage	7th & A 207 Renovation	$40,569.05	1110	2
2013	Anchorage	ESH 1st Floor South Offices Reconfiguration	$36,881.80	1966	1
2013	Anchorage	UC131 Remodel	$48,186.13	1016	2
2013	Anchorage	LIB 305 ADA & Storage	$14,246.29	1605	1
2013	Anchorage	UC 103 Remodel	$6,922.37	982	1
2013	Anchorage	ANSEP 205/204A/204A1 Reconfiguration			

2014	Anchorage	ANSEP 205/204/204A1 Reconfiguration			
			$99,207.86	1210	3
2013	Anchorage	Asset Integrity and Corrosion Lab	$273,472.25	8352	1
2013	Anchorage	RH 108 Improvements	$42,515.90	2070	1
2013	Kenai	KPC Library Renovation			
2014		KPC Library Renovation			
2015		KPC Library Renovation			
2016		KPC LIBRARY RENOVATION (BROCKEL RENEWAL)			
			$150,058.18	3941	2
2013	Kenai	KPC UC 117 Office Improvements			
2014		KPC UC 117-118 Classroom/Office Remodel			
			$64,600.96	1606	2
2014	Anchorage	UAA Alumni Relations Office Renovation	$338,027.55	1095	5
2014	Anchorage	UA SSB ITS Reception Renovation			
2015		UA SSB ITS Reception Renovation			
			$137,365.92	642	4
2014	Anchorage	ITS Dept Phase 1 Renovations	$118,676.90	1184	3
2015		UAA LRC Renovation	$66,173.13	4910	1
2015		UAA Bookstore Renovation			
2016		UAA BOOKSTORE RENOVATION			
			$1,604,756.33	15887	3
2015		UAA Parking Services Relocation-ULA			
2016		UAA PARKING SERVICES RELOCATION			
2016		UAA FP&C R&R (ULA PARKING SVCS RELOCATION)			
			$173,302.08	846	4

2015		UAA ANSEP Academy Remodel (see also 11582 & 194003-19013 & 243216)			
2015		UAA ANSEP Academy Remodel (see also 10050 & 194003-19013 & 243216)			
2015		UAA ANSEP Academy Remodel (see also 104110-11582/10050 & 243216)			
2015		UAA ANSEP Academy Remodel (see also 104110-11582/10050 & 194003-19013)			
2015		UAA ANSEP Academy New Kitchen			
			$400,065.68	12169	1
2016		UAA FP&C M&R (NSB ANIMAL HOLDING ROOMS)			
2015		UAA NSB Animal Holding Rooms			
2015		UAA NSB 235 Animal Holding Room			
2016		UAA NSB 235 ANIMAL HOLDING ROOMS			
			$168,740.98	1970	3
2015		UAA ULA 128 Driving Simulator	$31,613.78	1568	1
2015		UAA CPBB RH302/303 Renovations	$28,850.26	1789	1
2015		UAA HSB 107 Reconfiguration			
2016		HSB 107 RECONFIGURATION			
			$26,484.51	581	2
2015		UAA CPISB 332D Reconfiguration	$12,475.21	229	2
2015		KOC Campus Center Lobby Remodel	$31,947.10	1505	1
2016		UAA BEATRICE MCDONALD BUILDING RENEWAL (PSB-CPDS RENOV)			
2016		UAA BEATRICE MCDONALD BUILDING RENEWAL (PSB-CPDS RENOV)			

			$426,211.32	3182	3
2016		UAA WFSC SUITE 142 REMODEL			
2016		UAA FP&C R&R (WFSC SUITE 142)			
			$378,124.20	3894	3
2016		RH 122/124 DEAN OF STUDENTS IMPROVEMENTS	$63,800.00	2386	1
2016		KPC IT/ETT RENOVATION (WARD 118/119 RENOVATION)	$27,316.96	1297	1
2016		KOC WOODSHOP UPGRADES	$114,822.06	1521	3
2016		MSC BOOKSTORE RENOVATION	$170,810.73	1728	3
2007		Hutchison Renovation	$11,485,030.21	134161	3
2014		Bristol Bay Applied Sciences Bldg	$1,717,111.14	3531	6
2013		Bristol Bay Science Lab	$1,163,350.71	3293	5
2013		Kuskokwim Voc-Tech Building	$864,737.81	23797	1
2012		Arctic Health CANHR Health Clinic	$2,153,058.24	112124	1
2013		Kuskokwim CANHR Health Clinic	$1,197,778.91	8368	3
2015		Irving 1 Repurpose for Veterinary Medicine	$4,222,599.19	20146	4
2015		Bunnell E-Learning Move	$494,621.75	1715	5
2016		Lola Tilly Office Conversion	$454,099.05	15827	1
2014		Palmer Kerttula Hall 2nd Floor Renovation	$362,067.31	2620	3
2013		CTC Aviation Hangar Renovation			
2013		CTC Aviation Hangar Renovation			
			$1,680,227.64	11974	3
2016		Kuskokwim Campus Library Reconfiguration	$374,646.38	15108	1

2013		Bunnell 230 Office & Air Handler Ph2	$154,653.27	2140	3
2015		CTC Hangar Office Buildout	$177,209.34	1387	3
2013	Anchorage	UAA RH110 Renovation			

Appendix B

Statgraphics Data Table

FINAL COST	SQUARE FOOTAGE	RENO/FINISHES/MEP	LN(Cost)	LN(SqFt)
96217.22	1899	2	11.47436367	7.549082711
137632.45	2656	2	11.83234198	7.884576511
123078.32	2380	2	11.72057617	7.774855767
24136.42	871	1	10.09147716	6.769641977
129459.01	4593	1	11.77111961	8.432288684
33637.39	823	2	10.42339342	6.712956201
36009.20	834	2	10.49152985	6.726233402
40569.05	1110	2	10.61076063	7.012115294
36881.80	1966	1	10.51547335	7.583756301
48186.13	1016	2	10.78282648	6.923628628
14246.29	1605	1	9.564251722	7.380879036
6922.37	982	1	8.842513317	6.889591308
99207.86	1210	3	11.50497252	7.098375639
273472.25	8352	1	12.51895544	9.03025631
42515.90	2070	1	10.65763334	7.635303886
150058.18	3941	2	11.91877835	8.279189777
64600.96	1606	2	11.07598454	7.381501895
338027.55	1095	5	12.73088269	6.998509642
137365.92	642	4	11.83040356	6.464588304
118676.90	1184	3	11.68415999	7.076653815
66173.13	4910	1	11.10002979	8.499029221
1604756.33	15887	3	14.28848248	9.673256444
173302.08	846	4	12.06279149	6.74051936
400065.68	12169	1	12.89938401	9.406647013
168740.98	1970	3	12.03612017	7.585788822
31613.78	1568	1	10.36134827	7.357556201
28850.26	1789	1	10.26987429	7.489412084
26484.51	581	2	10.18431539	6.364750757
12475.21	229	2	9.431499149	5.433722004
31947.10	1505	1	10.37183665	7.316548177
426211.32	3182	3	12.96269056	8.065265209
378124.20	3894	3	12.84297799	8.267192186
63800.00	2386	1	11.06350847	7.777373603
27316.96	1297	1	10.21526312	7.167809184
114822.06	1521	3	11.65113894	7.327123292
170810.73	1728	3	12.04831138	7.454719949
11485030.21	134161	3	16.25655502	11.80679302
1717111.14	3531	6	14.35615387	8.169377262
1163350.71	3293	5	13.96681495	8.099554282
864737.81	23797	1	13.67018163	10.0773148
2153058.24	112124	1	14.58239983	11.62736068
1197778.91	8368	3	13.99597949	9.032170186
4222599.19	20146	4	15.25596142	9.910761037
494621.75	1715	5	13.11154861	7.44716836
454099.05	15827	1	13.02607062	9.669472621
362067.31	2620	3	12.79958541	7.870929597
1680227.64	11974	3	14.33443984	9.390468467
374646.38	15108	1	12.83373787	9.622965817
154653.27	2140	3	11.94894092	7.668561108
177209.34	1387	3	12.08508701	7.23489842

Appendix C

State of Alaska Construction Location Factors Table

City - Borough - Region	Location Factor	Addition Above Base
Alaska Gateway	125.2	25.20%
Aleutian Region	154.5	54.50%
Aleutians East	128.7	28.70%
Anchorage (Base)	100	0.00%
Annette Island	124.4	24.40%
Bering Strait	181.2	81.20%
Bristol Bay Borough	128.7	28.70%
Chatham	124.4	24.40%
Chugach	108.5	8.50%
Copper River	113.9	13.90%
Cordova	108.5	8.50%
Craig City Schools	112.4	12.40%
Delta/Greely	119.63	19.63%
Denali Borough	119.63	19.63%
Dillingham City Schools	133.54	33.54%
Fairbanks	105	5.00%
Galena	139.3	39.30%
Haines	112.4	12.40%
Hoonah City Schools	124.4	24.40%
Hydaburg City Schools	124.4	24.40%
Iditarod Area Schools-Yukon River Village	143.05	43.05%
Iditarod Area Schools-Kuskokwim River Village	154.5	54.50%
Iditarod Area Schools-Landlocked Village	160.9	60.90%
Juneau City/Borough Schools	103.6	3.60%
Kake City Schools	122.9	22.90%
Kashunamuit	152.36	52.36%
Kenai Peninsula-Kenai/Soldotna	98.6	-1.40%
Kenai Peninsula-Homer Area	105.5	5.50%
Ketchikan	110.8	10.80%
Klawock City Schools	124.4	24.40%
Kodiak-Kodiak Island	112.4	12.40%
Kodiak-Village	124.4	24.40%
Kuspuk Schools	154	54.00%
Lake & Peninsula-Gulf of Alaska Village	124.4	24.40%
Lake & Peninsula-Bristol Bay Village	136.04	36.04%
Lake & Peninsula-Landlocked Village	160.73	60.73%
Lower Kuskokwim-Bethel	156.1	56.10%
Lower Kuskokwim-Villages	167.1	67.10%
Lower Yukon	167.1	67.10%
Mat-Su Borough Schools-Palmer - Wasilla	99	-1.00%
Mat-Su Borough Schools-Other Areas	105.5	5.50%
Nenana City Schools	116.5	16.50%
Nome City Schools	156.1	56.10%
North Slope Borough-Barrow	171.8	71.80%
North Slope Borough-Villages	182.2	82.20%
North Slope Borough-Atqasuk/Pt. Lay	199.9	99.90%
Northwest Arctic Schools-Kotzebue	150.18	50.18%

Northwest Arctic Schools-Villages	181.5	81.50%
Pelican City Schools	124.4	24.40%
Petersburg City Schools	110.8	10.80%
Pribilof Island Schools	164.7	64.70%
Sitka City Borough	110.8	10.80%
Skagway City Schools	110.8	10.80%
Southeast Island Schools	123.19	23.19%
Southwest Region Schools	140.91	40.91%
St. Mary's School District	159.75	59.75%
Tanana City Schools	134.65	34.65%
Unalaska City Schools	140	40.00%
Valdez City Schools	109.3	9.30%
Wrangell City Schools	110.8	10.80%
Yakutat City Schools	115.4	15.40%
Yukon Flats-Village on Road System	122.95	22.95%
Yukon Flats-Village on River	141.8	41.80%
Yukon Flats-Landlocked Village	159.73	59.73%

Appendix D

Inflation Index Factor Table

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	HALF1	HALF2
1990	127.4	128.0	128.7	128.9	129.2	129.9	130.4	131.6	132.7	133.5	133.8	133.8	128.7	132.6
1991	134.6	134.8	135.0	135.2	135.6	136.0	136.2	136.6	137.2	137.4	137.8	137.9	135.2	137.2
1992	138.1	138.6	139.3	139.5	139.7	140.2	140.5	140.9	141.3	141.8	142.0	141.9	139.2	141.4
1993	142.6	143.1	143.6	144.0	144.2	144.4	144.4	144.8	145.1	145.7	145.8	145.8	143.7	145.3
1994	146.2	146.7	147.2	147.4	147.5	148.0	148.4	149.0	149.4	149.5	149.7	149.7	147.2	149.3
1995	150.3	150.9	151.4	151.9	152.2	152.5	152.5	152.9	153.2	153.7	153.6	153.5	151.5	153.2
1996	154.400	154.900	155.700	156.300	156.600	156.700	157.000	157.300	157.800	158.300	158.600	158.600	155.800	157.900
1997	159.100	159.600	160.000	160.200	160.100	160.300	160.500	160.800	161.200	161.600	161.500	161.300	159.900	161.200
1998	161.600	161.900	162.200	162.500	162.800	163.000	163.200	163.400	163.600	164.000	164.000	163.900	162.300	163.700
1999	164.300	164.500	165.000	166.200	166.200	166.200	166.700	167.100	167.900	168.200	168.300	168.300	165.400	167.800
2000	168.800	169.800	171.200	171.300	171.500	172.400	172.800	172.800	173.700	174.000	174.100	174.000	170.800	173.600
2001	175.100	175.800	176.200	176.900	177.700	178.000	177.500	177.500	178.300	177.700	177.400	176.700	176.600	177.500
2002	177.100	177.800	178.800	179.800	179.800	179.900	180.100	180.700	181.000	181.300	181.300	180.900	178.900	180.900
2003	181.700	183.100	184.200	183.800	183.500	183.700	183.900	184.600	185.200	185.000	184.500	184.300	183.300	184.600
2004	185.200	186.200	187.400	188.000	189.100	189.700	189.400	189.500	189.900	190.900	191.000	190.300	187.600	190.200
2005	190.700	191.800	193.300	194.600	194.400	194.500	195.400	196.400	198.800	199.200	197.600	196.800	193.200	197.400
2006	198.300	198.700	199.800	201.500	202.500	202.900	203.500	203.900	202.900	201.800	201.500	201.800	200.600	202.600
2007	202.416	203.499	205.352	206.686	207.949	208.352	208.299	207.917	208.490	208.936	210.177	210.036	205.709	208.976
2008	211.080	211.693	213.528	214.823	216.632	218.815	219.964	219.086	218.783	216.573	212.425	210.228	214.429	216.177
2009	211.143	212.193	212.709	213.240	213.856	215.693	215.351	215.834	215.969	216.177	216.330	215.949	213.139	215.935
2010	216.687	216.741	217.631	218.009	218.178	217.965	218.011	218.312	218.439	218.711	218.803	219.179	217.535	218.576
2011	220.223	221.309	223.467	224.906	225.964	225.722	225.922	226.545	226.889	226.421	226.230	225.672	223.598	226.280
2012	226.665	227.663	229.392	230.085	229.815	229.478	229.104	230.379	231.407	231.317	230.221	229.601	228.850	230.338
2013	230.280	232.166	232.773	232.531	232.945	233.504	233.596	233.877	234.149	233.546	233.069	233.049	232.366	233.548
2014	233.916	234.781	236.293	237.072	237.900	238.343	238.250	237.852	238.031	237.433	236.151	234.812	236.384	237.088
2015	233.707	234.722	236.119	236.599	237.805	238.638	238.654	238.316	237.945	237.838	237.336	236.525	236.265	237.769
2016	236.916	237.111	238.132	239.261		241.038								